Science education

TEACHING FOR UNDERSTANDING SCIENTIFIC CONCEPTS AND PRINCIPLES USING METAPROCEDURAL REORGANIZATION: A STUDY OF STUDENTS' UNDERSTANDINGS ABOUT THE BIOCHEMICAL ACTIVITY OF THE CELL

By

Safa Amin Zaid

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

College of Education
Department of Curriculum and Instruction

1988

ABSTRACT

TEACHING FOR UNDERSTANDING SCIENTIFIC CONCEPTS AND PRINCIPLES USING METAPROCEDURAL REORGANIZATION: A STUDY OF STUDENTS' UNDERSTANDINGS ABOUT THE BIOCHEMICAL ACTIVITY OF THE CELL

By

SAFA Amin Zaid

Inhedler (1974) defined metaprocedural reorganization as the process learners use to reach a theory that allows specific explanation of phenomena and generalization to other situations. For learners to reach this level of understanding, Inhedler proposed that learners must become aware of how their own personal theories developed, which frequently parallels the historical evolution of scientific ideas. The problem which this thesis addresses is: What effects will science teaching based on metaprocedural reorganization have on high school students' understandings of contemporary theories of biochemical activity of the cell?

Twenty eleventh grade females in a Jordanian high school were randomly assigned to treatment and control groups. Students in both groups were pretested and posttested with an open-ended, essay test designed by the author. The treatment group was given seven enriched lessons stressing the logical, historical development of the contemporary theories about the topic. The control group continued to work in regular classes.

Test data and audiotapes of lessons were analyzed to determine students' reasoning on entry and throughout instruction. Textbook

content was also analyzed for historical development of pertinent concepts.

Significant differences were found between experimental and control groups in the posttest, using an ANCOVA design analysis. However, in spite of the pretest-posttest gains by the experimental group in functional knowledge, it was apparent that some students had not acquired correct propositional knowledge of the concepts studied. These students demonstrated coherent, integrated misconceptions of various concepts that underlie understanding of the topic. For example, students whose entry level knowledge included plant mass deriving from organic compounds formed "originally by plants from nothing but water," were the same who stated that "water is used to produce energy." Also they were the same who stated in the posttest that organic compounds formed just from energy.

The author suggests that students' misunderstanding for propositional knowledge is a consequence of a curriculum which, throughout their school experience, has not required students to integrate their understanding in biology with fundamental principles of physics and chemistry. Also, theories are confounded by textbooks which mix today's paradigms with prior ones without showing the reasoning

To: the memory of my mother,
Khatema; my father Mohammed
Amin; my husband, Hussein;
and my sons, Ahmad, Ebrahim,
and Mohammed Amin

ACKNOWLEDGEMENT

I would like to thank Dr. James J. Gallagher, my major advisor and Chairman doctoral committee, for the guidance, suggestions and knowledge he provided me throughout the research.

I would like also to thank Dr. Smith my committee member for his help in organizing the proposal and reporting the study results.

Iam also indebted to my doctoral committee members Dr. Kenneth, Neff, and Dr. Richard McLeod for their times and support throughout this research. Also Sincere thanks to Dr. Ben Bohnhorst and Dr. John, Vinsonhaler. Dr. Bonhurst's suggestions contributed immeasurably to the writing of this dissertation. Dr. Vinsonhaler's suggestions contributed to allowing use the personal computer in quantitative data analysis.

Special thanks goes to my husband, for his support throughout the entirety of my doctoral studies. My family in Jordan deserves special recongnition for their encouragement and support. I would also like to thank my class mates Rowayda and Layla for the support they gave through collecting the data.

Finally, I would like to thank Sult Non-Profit Organization and Sage Foundation for the financial help that made it possible to accomplish my doctoral degree.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE **PAGE**

CHAPTER I

The scholar is still scholar as long as he asks for knowledge. If he thinks he knows enough then he becomes ignorant (the Prophet Mohammed).

INTRODUCTION

Complex, conceptual structures, such as those used to explain the biochemical activity of the cell, often are poorly understood by many students in high school and college science courses. As a technique to help students improve their comprehension of such complex subject matter, and to expand our understanding of why students have difficulties in learning specific concepts, a metaprocedural intervention (Inhedler, 1974) was tested. This method implies that students will try to unify their partial theories as they learn science in the same way scientists unified their partial theories in developing present day scientific knowledge. The strategy is to guide students through the questioning and logical reasoning similar to that scientists went through as they worked to understand natural phenomena.

Background

Student perspective

As a youth, I liked to read about science. The science that I read was different from what we studied in school. School science was something to memorize for a test. But I would then spend hours after school reading about the universe, about living things, and about other topics concerning natural phenomena.

There was no enjoyment in school science, because of the burden of trying to overcome my weak memory as I rehearsed both the laws and the scientific material for tests. The derivation for the law was presented in the textbook. However, It did not detail the everyday phenomena that scientists studied as they developed their explanation. Such information might evoke similar curiosity in students and encourage them to follow the logic of the discovery.

I graduated from high school with high grades, in part because of good scores in algebra and trigonometry. I wanted to study engineering in Egypt, since there was no college of engineering at the University of Jordan. At that age, however, I was naive and believed what some students who were studying chemistry at the University of Jordan had told me. One of them told me "You can stay home and study chemistry. It is so fascinating at the university. You can understand everything through chemistry." I was encouraged by what she told me, of being able to understand the components of oil, paper, clothes, soap and other familiar phenomena. Even after I told her about the difficulty I had in studying chemistry in school, she told me that it was different at the university and that I would not have to memorize, since the teaching was theory oriented.

On entering the university, I found that the situation was no better than at school. The theory was there, but there was no way to know where the theory had come from or why we had accepted it in the first place. In school, students have to memorize the chemical equations, while at the university students have to memorize the routine of the application of fundamental principles in solving certain problems

situation

mual a

reaction

It w

I had bee

from the

education

would use

were simp

that they

science b

never kne

outer spa

sense to

mother

applied t

presented

noted at

scientists

stimulus,

phenomenon

science be

questions

comprehens

ways of s

problems. Teaching did not relate, in any way, to everyday life situations. Chemistry lab was considered a "cooking room" and the lab manual a recipe book. I wanted to quit, but the fear of my family's reaction obliged me to continue to get a degree.

It was purely by accident that I discovered it was not science that I had been studying all those years. I once picked up a physics book from the library at the University of Jordan for an assignment in an education course. In this assignment, I was asked to bring material I would use to teach. This was the first time I realized that scientists were simply trying to discover the laws that govern the universe; and that they used experiments to verify their hypotheses. All I knew about science before was that it was formulae brought on by "supermen." I never knew that Newton's principles involved the movement of objects in outer space. While I memorized scientific principles, it had not made sense to me that every object would continue to move if not stopped. Neither the book nor the teacher ever explained that Newton's law applied to outer space and that the friction and air resistance on earth prevented objects here from behaving as explained by Newton's law. As I looked at the cosmos maps hanging over classroom walls, I was amazed how scientists could predict the path of the orbit. Although I was studying calculus, I did not know that Newtons' principles explained this phenomenon. It was only through studying the history of science, that science began to make sense to me. Scientists were answering the same questions I had asked myself in everyday life. I found their logic comprehensible and shortly learned what had not made sense to me through years of study.

Research

education

in the

Researche

1991, re

Nussbaum

students

Resea

and to be

which was

Japanese s

and Speran

information

in other f

Al

Misconcept

Misconcept

in work (

Furthe

Misconcept

which "Mis

students a

identified

the cross

cross spe

native and

Research on Students' Misconceptions: Through my graduate study in education, I was glad to see that research on science teaching focused on the same issues that had been so difficult for me to learn. Researchers in both cognition and science teaching (Wiser and Carey 1982, re: heat; McClosky 1983, Clement 1982 re: force and motion; Nussbaum and Novak 1976, re: earth) show that many misconceptions that students have, are similar to the ones found in the history of science.

Researchers in science teaching also show that these misconceptions tend to be universal. For example, the misconception about force and motion was shown to be shared by many students world wide including Lebanese students (Za'rour, 1975) and Italian students (Aiello-Nicosia and Sperando-Mineo, 1980). Gilbert and Watts (1983) reported many international studies about misconceptions that seemed to be identical to other findings in many parts of the world.

Although there is a growing body of research on students' misconceptions worldwide, I still found little data about students' misconceptions in the country where I had studied and in which I intend to work (Jordan).

Furthermore, in the U.S., there is still little data about students misconceptions at higher grades. There is some data about force and motion (Minstrell, 1984), but, there are few data from among high school students about the biochemical activity of the cell. The data identified by Wandersee (1983) and Treagust (1986) in photosynthesis were cross age studies. There were few data on how high school students process specific scientific information through instruction or how they receive and interpret information in a specific subject matter. Research on misconceptions tends to depend on tests or clinical interviews, to obtain information about students' naive ideas. The research did not stress specifically how students received given information and interpreted it according to their entry-level knowledge in the conventional environment of teaching (classroom).

Teacher perspective

Through my teaching career, I tried to avoid erroneous linkage between phenomena and the scientific concepts by attaching the abstract subject to the familiar phenomena through instruction. However, I found that many students were finding science a difficult subject, one they had to swallow like an ill-tasting medicine, and in small ready-made packages. The students preferred small summaries of the important points in the book, making it still easier to rehearse. They enjoyed the method of didactic teaching, even in chemistry. Students did not study science using a scientific reasoning process, they rehearsed it as poetry. They simply wanted to know which important principle they needed to rehearse, and how they should apply these principles to exhibit the routine of solving scientific problems.

I suspect the reason for such behavior, besides being the method that many teachers had used since elementary school, and the one students most commonly used when studying, was that science is difficult to comprehend. Discussing one phenomenon and relating it to a scientific concept is not enough to make students formalize a scientific theory, and use it independently in solving problems in the world outside school. Scientific concepts (especially the revolutionary ones) are composed of abstract relationships, formulated by integrating the reasoning about many phenomena.

The historical experiments were evident in the science textbooks, but they did not teach students about the process by which the scientific information was developed. The hypotheses and the premises were not included, only the conclusions the scientists drew from them. There was no emphasis on the questions asked or scientists' hypothesis that derive the experiment. No reason was given why the scientist did the experiment or what he was trying to prove.

As a teacher, I kept asking myself if it was possible to change students' methods of studying science. This could be achieved only if students understood that scientific information was discovered by human efforts and was not just facts to be memorized. How could this be done? My graduate study in education was targeted at discovering if there was a solution to such a problem.

Teaching the biochemical activity of the cell

There were two primary reasons for choosing this topic for the study. First, this topic is part of the biology curriculum in Jordan as well as other nations. It is an important topic, including many concepts useful in understanding and explaining everyday experiences. Topics such as photosynthesis, respiration, nutrition, genetics, agriculture, and ecosystem are related to this comprehensive subject. However, the traditional textbook presentation is limited, since it concentrates on just photosynthesis, respiration, and the structure of DNA.

Secondly, teaching this topic is difficult. It is difficult for students to restructure their explanations of familiar phenomena

according to these scientific concepts. For example, students have trouble linking photosynthesis to agricultural problems, respiration to the mechanisms of life, and DNA to species adaptations and feeding habits.

Initially this feeling of the difficulty that students face, was driven from research on teaching this issue, (Roth, Smith & Anderson), my personal experience, and people I know exemplified the same difficulty in learning this topic. In studying this issue, it took much time and many efforts to move from the most naive stage to the stage of scientific understanding. During my elementary school days, I used to look from our balcony to the trees stretched in the valley underneath. I wondered how our mouths, at the upper end of our bodies took in food, while the trees' mouths (roots) took nourishment from the ground. While I had some idea about photosynthesis, I still never attached that knowledge with my image of how a plant takes its nutrition. For me, photosynthesis meant the ability of plants to absorb carbon dioxide and produce oxygen during the day time; and that plants will produce just carbon dioxide at the night. This was all I understood about photosynthesis.

There were school experiments such as planting seeds in cotton, pouring water over them, observing how seeds grew, and returning the plant to the teacher to get graded. At that time, I never related the experiment to photosynthesis. I learned the importance of water in plant nutrition and nothing more.

One of the earliest sciences we studied our freshman year was biochemistry. All I knew from my early school years was that plants give off oxygen and animals take it. I was so surprised to learn how, in respiration, our bodies act on organic compounds formed through photosynthesis, to produce the energy necessary for life; how carbohydrates in plants, and glycogen in animals, are a connection of glucose molecules, and how chlorophyl in plants resembles vitamin D in animals.

Those freshman year studies did not mean I had a complete scientific idea about the topic. It took longer for me to understand that all animal tissues are composed of organic compounds, in which the primary carbon bonds are formed through photosynthesis. I might have been confused by the emphasis the textbook placed on glucose burning in the body, so that I did not perceive the other function of photosynthesis, which is to construct the interchangeable parts (amino acids) that are used in building body tissues.

It was an experiment in a science textbook for art students that helped me understand. This experiment showed how plants can grow only from minerals and water. I already knew, from my undergraduate study, how organic material is formed through photosynthesis. From this experiment, I realized that if plants only absorbed slight quantities of minerals from the soil, then the only other possibility for building body tissues would be what the plant synthesizes through photosynthesis. Also knowing that organic compounds, such as protein, nucleotides, etc. contain a series of carbon bonds in addition to a small percentage of other elements, such as nitrogen, phosphate and sulfur, strengthened my conclusion.

Through my graduate study in education, I discovered that teaching this topic was a problematic issue. A growing number of studies showed that students had a serious misunderstanding in comprehending many issues that underlie this topic (Roth, 1985; Treagust amd Haslam, 1986; Wandersee, 1983; Smith et al., 1986; Bishop et al., 1985; and Smith and Anderson, 1986.

However, when studying the way Roth (1985) handled it, I came to a point that if students, at best, understand the meaning of "plant makes its food by itself" as "food is a source for energy" then they would come to a conceptual structure similar to the one I had utilized in college. This is due to the fact that Roth did not include the function of soil in her treatment. Roth's emphasis on the way students use technical terms, explained her design for the treatment. This design depended on making students' understanding the scientific definition of food, and using this understanding to develop explanations of everyday life phenomena (induction). Once the stipulated definition of food was developed, reasoning about evidences and alternatve ideas was used. Her treatment did not depend on students' own inferences in building this scientific definition.

Textbooks often try to make scientific definitions understandable, using metaphoric language for abstract concepts such as energy heat, etc. Students are then asked to generalize these understandings to explain everyday biological phenomena. Acoording to Ausubel, there are organized bodies of knowledge that are worth teaching and learning. Although the specifics of science change rapidly, basic principles tend to manifest impressive longevity. The basic objective of a high-school biology course should be teaching of those broad biological ideas which constitute part of general education. As cited also in Shulman and Tamir (p. 1104, 1973), Schwab did not agree with Ausubel that basic principles tend to manifest impressive longevity. Schwab stated that "the learner should become cognizant of science as a product of fluid enquiry, and understand that it is a mode of investigation which rests on conceptual innovation. Development of understanding proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by." Schwab did not consider that students would be able to discover these ideas of fluid inquiry by themselves, saying, "it is virtually impossible to provide a step-by step description of the method of fluid enquiry, for, while stable enquirers permit themselves some flexibility in the interpretation of data, there is practically no limit to the flexibility with which the fluid enquirer may work. The detection of inadequacies in current structures is an act of creative "insight"which has no known method. The revision of a structure or the invention of a new one is an act of creative imagination for which, again, there are no known methods. Even the timing, the occasion, for fluid enquiry is indefinitely variable" (Schwab 1964 b, p. 42). Schwab also took the position of isolated enquiry in each scientific field saying "if it is difficult to sketch the course of fluid enquiry, it is impossible to describe th substantive structures of the sciences in general. They are so because of the very character of substantive structures and the role they play" (p.46).

I did not agree with Ausubel that basic principles in science does not change, for the history of science showed it really changes.

Considering it otherwise would make students learn just the earlier theories from the 17th, 18th and 19th centuries.

But still I think that Schwab's proposition for science as enquiry could not work with his second suggestion of isolated conceptualization in every field. The biggest discovery in the biological fields in the twentieth century became possible by integrating many scientific fields. The question now becomes, how can we ask students to make judgment between two theories if they lack the essential background in other scientific fields which allow their discoveries? Merely presenting historical experiments could allow students to accept a theory just because the teacher said it is so, not because they really understand and judge its strength.

As explained by Shulman and Tamir 1973, Schwab did not consider students to be able to inquire about revolutionary science by themselves. The ideas should be presented to them systematically to make judgment about (science as enquiry). My treatment is derived from my strong feeling that, even if students could not make exact reasoning about revolutionary scientific concepts by themselves, they should be given the opportunity to understand why scientists postulated the scientific definitions. Their guidance for accepting the theory should come from their restructuring of their own common sense knowledge. The phenomena of misconceptions show great similarities between the types of reasoning given by students and the ones observed in the history of science when explaining the phenomena, suggesting that students should be guided to internalize the restructuring of revolutionary scientific explanation.

This introduction provides the rationale for my study, and the problem for which I felt the need to find a solution which enables students to comprehend scientific concepts, using their own inference from the phenomena.

Metaprocedural Reorganization

I chose metaprocedural reorganization as a method of treatment because of the difficulties I had faced, and the research findings that show similar difficulties many students face in learning and understanding science.

The method I adopted in teaching the biochemical activity of the cell is illustrated in Figure 1:

```
       student's          |              |  metaprocedural
   general knowledge      |              |   reorganization
     ----------->         |              |  <-----------
        time     |        |              |
                 |        |              |
                \ /       |______________|
```

At the bottom of the U shape, students form partial theories that contradict each other, when trying to explain their general observation.

U Shape

Figure 1

A metaprocedural reorganization is a term stipulated by Inhedler (1974) to describe the way children form a unified theory to allow correct predictions and generalizable explanations. For Inhedler, this stage does not come in one step, instead it follows a systematic path of reconciliation. The first step in forming the theory (the left top of the U shape in Figure 1) is covert implied knowledge. People do things because they know from experience that it works; but as happened in the history of science, when people tried to understand how and why things work, a key problem with misconceptions began. After forming many partial theories, each of which worked well for one event, although perhaps incompatible with others, the unification process began. In this process a more powerful theory was formed to explain many events related to the problem. At the end of this stage, children (as scientists) would be able to solve many problems they face in everyday life, using a rather comprehensive theory. To form this comprehensive theory, students need to become procedurally aware of how their concepts were developed through all the stages of forming the theory.

This implied that children had to form a systematic reasoning for many events, even if this reasoning implied misconceptions at the primary stages, since it would lead children to further question the incompatibility between their primary theory and another incompatible experience. This ultimately would lead children to apply their knowledge and generalize it to solve any future problems, using one powerful theory they learned from their primary experiences. As it evident from the nature, extent, and persistence of misconceptions, few students do this spontaneously. Instead, most students make sense of bits and pieces of scientific knowledge but fail to integrate these components into a coherent whole.

Metaprocedural method and students' learning

The study adopted this method "illustrated by the U-shape" (Brown et al., 1983) to understand scientific learning. Students read the textbook, know on the surface how to solve problems, and give correct answers to specific questions which involve descriptions (e.g.,. what) of the phenomena (see Fig 1 on the upper left end of the U shape). However, if we try to modify the problem or to ask them "how and why" questions, ask them to formulate a theory and rationalize the events they describe, they give an answer which reflects their non-integration of their knowledge. These explanations might be similar to those of scientists at one time in the history of science. However, students' naive unintegrated theories would change according to their experience as they become aware of the incompatibility of their theory and experiences. Dissonance thus created often leads to restructuring of their theories. These occurrences which are shown at the bottom of the U shape, deviate more and more from acceptable scientific information.

At the primary stage, explanations can still be weaker and more naive than the students' initial implied knowledge. As students try first to stabilize their explanation according to these partial theories, they frequently are "blinded" from new observations that are contradictory to their thinking. When reaching the stage of being aware of how different, partial theories contradict each other, they become more able to comprehend (or even construct) a powerful coherent theory to solve scientific problems in the manner of scientists. Here students reach the ultimate goal in the upper right corner of the U shape (see Fig. 1). They make correct predictions and reasoning about the phenomena, instead of memorizing scientific information that can result in misconceptions.

Instruction and Metaprocedural reorganization

Carey, Gelman and many cognition theorists do not agree with the Piagetian viewpoint that the complete unification process used to reach present scientific theory can be achieved solely by students' natural inference even for those who have reached formal operational stage. In the history of science, the more advanced theories were achieved after long periods of time. According to Vygotsky, the social cultural factor plays a big role in this process. This highlights the problems students have in comprehending revolutionary scientific theories.

This method could be of value, however, in understanding the sequence which should be followed in instruction. For Carey (1982), students' reasoning about the phenomena reflects their entry-level conceptions. These can vary from one student to another, even in the same mental developmental stage, depending on whether the students acquire the prior information that is necessary to restructure their theories. Carey contends that if the necessary information was not available in the social cultural environment, then the students would never reach this operational unification stage in learning science.

I hypothesized that by incorporating appropriate new information and observation about specific phenomena, carefully chosen to match the scientists' observations, students would be able to follow the logical path of restructuring scientific theory. This could allow students to see the incompatibility between the different partial theories formed from different observations. Thus, as students followed the logical, historical development of a scientific idea, they would be able to unify separate, component theories into a unified scientific theory to explain all their observations for a given scientific concept.

The teacher can use many observations, asking students to back them up with explanations. These phenomena would be carefully chosen and introduced systematically, matching the ones observed by scientists throughout history. Thus, students would learn about some of the difficult conceptual problems which troubled scientists, because these are often the same conceptual problems that trouble students as they try to learn science. Carey (1984) said that Kuhn's paradigm could be used to determine what question would be asked about the phenomena; what hypotheses to propose; what rational conclusion can be expected as we watch the process of scientific learning by students. This implies that we could use questions which ask about the phenomena (and which changed historical' scientists explanations) to make students question their own belief about the same phenomena and watch the restructuring of students theory in the same way as scientists. Through this process, students become aware of how new explanations differ from their naive hypotheses. Students may be helped by following the same path scientists used to restructure their theories. This could advance students' understanding and give them greater power to explain a given phenomena.

An example of restructuring used in teaching the biochemical activity of the cell is: Students know, in general, that soil, light, water and air are important for life, but they do not understand specifically why they are important. If they were asked the first question which led to the scientific restructuring of the theory, "where does the weight of plants come from?" they may say "from soil". The teacher could instruct the student to observe the phenomena that led scientists to change their theory. If a plant grows in a small pot of soil, the plants gain less than 0.1% of its weight from the soil; students would then consider water as the source of weight. Priestly's experiment would then be introduced to allow students to consider that carbon dioxide also enters into the photosynthesis process.

The students could be directed to relate the work of photosynthesis to respiration to form a single coherent theory to explain the two observations. Priestly noticed plants absorbed carbon dioxide, while animals release it. This is done by giving students an example: Burning oil releases carbon dioxide and water vapour with energy, the reverse happens in photosynthesis. This could lead students to make analogies (Lavoisier's reasoning) between burning and respiration. This in turn leads them to understand that during this process of respiration (or any kind of burning), carbon dioxide, water and energy are released from the compounds formed from the raw material provided for the plant during photosynthesis. This procedure would continue throughout the history of science until students fully comprehended the biochemical activity of the cell in a unified integrated process. A thorough example of the questions the scientists asked about the phenomena, the observations the students had heeded, and the conclusions are in Appendix C.

Problem

Statement of the problem

Inhedler (1974) called the process the learner uses to reach a theory that allows him to explain the phenomena specifically and to gen

reco

inhe

own

deve

this

meta

unde

the

The

3) T

theo

activ

the

3) Bo

storr

based

infor

stude

Upon

A

her

metap

become

from

be ab

generalize this explanation into another situation, a metaprocedural reorganization. For learners to reach this level of understanding, Inhedler proposed that they must become procedurally aware of how their own personal theories had been developed, which frequently parallel the development of scientific ideas in the history of science.The problem this dissertation addresses: What affects will teaching, based on metaprocedural reorganization, have on high school students' understanding of contemporary theories of the biochemical activity of the cell?

The specific questions are:

1) To what extent do the connections made by students in their partial theories about scientific concepts which underlie the biochemical activity of the cell follow the same coherent conceptualization found in the history of science?

2) How is students' understanding of the contemporary concepts of the biochemical activity of the cell influenced by instructional treatment based on the logical, historical development of scientific ideas, by information presented in the textbook used for instruction, and by students entry level knowledge?

Hypothesis

Based on Inhedler (1974), a student would be able to master his or her understanding of the subject matter when they are able to metaprocedurally reorganize their theories. This would occur when they become procedurally aware of how their previous naive theories differ from new ones in explaining the phenomena. At this stage, students would be able to build a unified theory to explain everyday life phenomena using a coherent scientific view. Inhedler claims that this level of knowledge cannot be reached directly, in one step. Rather, it goes systematically, making more mistakes in the beginning, in the same way scientists do, until reaching an expert level of knowledge.

Using the Inhedler theory about the way students reorganize their concepts, and Vygotsky's theory about the importance of the teacher in affording the necessary social cultural experience to the learner, I hypothesize that a) students' construction of their theories of the issues that underlie the biochemical activity of the cell would be similar to the coherent constructions used throughout the history of science; b) reorganization of student concepts would be similar to scientists; providing the instructional approach would allow students to systematically examine the questions that enabled the restructuring of the naive theories in the history of science.

Specific hypotheses are (a) the students' method of connecting information about the concepts that underlie the biochemical activity of the cell would follow the same coherent conceptualization previously observed in the history of science; and (b) the types of conceptual changes that characterized scientific revolutions would also be important in the students' conceptual development.

Procedure

Ten Jordanian girls enrolled in an eleventh grade biology class were given seven enriched lessons that stressed the logical historical development of the fundamental principles of cellular biochemistry in addition to their continued readings from the textbook. The girls' knowledge was tested both before and after the lessons, using an open-ended essay test. In addition, tape recordings were made of all classroom interactions during the seven hours of instruction provided the experimental group. Students in the same group were also given homework to be answered after each lesson of instruction. A control group of ten girls were also pretested and posttested, using the same instrument. The control group had no intervention, however, and continued in their regular eleventh grade biology class based on the national curriculum. All twenty girls were volunteers and were randomly assigned to the experimental and control groups.

Statistical tests of differences between the control and experimental groups were used to examine the effectiveness of the treatment in reducing misconceptions in the students' explanations for everyday biological phenomena. Students' explanations about the phenomena related to the biochemical activity of the cell in pretests, posttests and lessons were used to answer the first question: Each students' answers to all questions were examined to see if there was a tendency to posses a common, coherent theory about all the concepts that underlie the biochemical activity of the cell in the same way it happened in the history of science.

The second question studied the effect of instruction, textbook information, and students' entry level knowledge of their comprehension of the topic. Comparisons were done on the effect of the textbook's conceptual organization. This included a) its expression of the development of this topic in the history of science; b) how this relates to the entry level knowledge of students, and c) the effect of the lo

th

th

de

pr

co

the

oth

tic

eco

pos

Ther

foll

tha

thin

only

make

wo

mi

logical organization of instruction on students' restructuring of their theories. This was accomplished by following the students' reasoning in the seven lessons of instruction, their homework and the test data. The development of the topic in the history of science, and the text presentation of the historical development of pertinent ideas, were also compared and contrasted.

Objectives

Inhedler proposed a procedure that students use to form their theory, just as scientists did. Scientists throughout history built coherent theories regarding all the concepts that underlie the biochemical activity of the cell; photosynthesis, respiration, ecosystem, etc. If this also held true for students, it would be a positive implication as a guide for designing science curriculum. Therefore, our objective of the research is to test Inhedler's proposal.

Another objective is to examine the influence of a treatment that follows the logical historical path of developing scientific theories (that underlie the biochemical activity of the cell) on students' thinking, including the effects of instruction and the textbook.

Limitations

One limitation is the small sample used in the study. There were only ten students in each of the experimental and control groups. This weakened generalization and reliability. From a practical stand point it would be too difficult for one researcher to sample a larger group and maintain a valid and effective evaluation of each students' reasoning, whil

less

the l

sever

on ac

requi

inclu

and l

the c

about

devel

study

photo

diffe

the s

(

the sa

in the

(

result

while keeping track of students' reasoning through dialogue in all the lessons.

Another limit is the allotted time to study the various concepts of the biochemical activity of the cell. Although this topic contained seven lessons in conventional instruction, the treatment also depended on additional concepts and particular types of inference that I feel required extra time to teach.

Overview of the Organization

This dissertation is divided into six chapters. Chapter One includes background material, a statement of the problem, assumptions and limitations of the study.

Chapter Two includes literature review. The first part discusses the theoretical basis of the study. The second part discusses research about students' misconceptions and compares it to the historical development of the subject.

The last section of the literature review is a background for the study. It discusses the previous research done specifically on photosynthesis, respiration, and the ecosystem. It also focuses on the different approaches taken to handle the problem of misconceptions and the specific treatment designed in this study.

Chapter Three is about methods. It gives a detailed description of the sample, the method used in collecting data, and the method followed in the analysis.

Chapter Four contains presentations and analysis of the students' results, including statistical and qualitative analysis.

diff

issu

acco

was

curr

last

cons

diss

Chapter Five presents several case studies, illustrating how different groups of students restructured their theory of the various issues that underlie the biochemical activity of the cell.

Chapter Six contains the summary, conclusions, implications and autobiography for the study. It discusses the reason that the treatment was unsuccessful with some students. Implications for instruction, curriculum, and research on science teaching are also discussed. The last part is an overview of the different stages, which I encountered in constructing the theoretical and methodological approaches of the dissertation.

CHAPTER II

LITERATURE REVIEW

Part 1. Theoretical Background about Metacognition

Introduction

The term metacognition in general refers to a person's awareness of his own thinking processes. This awareness was the criterion for learning maturity in the Piagetian tradition. They also felt the primary stage of theory formation is necessarily accompanied by misconception as part of the learner's effort to became consciously aware of occurrence of events, using the history of science as a metaphor (Brown et al., 1983).

However, the meaning of the word metacognition became ambiguous as theorists working in the information processing tradition (who frequently seek their metaphors for understanding theory development from computers), used the word "metacognition" in a different meaning. In this tradition, meta-cognition means consciously planning strategies to solve given problems.

Because the term carries two meanings, I will attempt to show how adherents to the Piagetian framework and the information processing framework each would approach specific issues related to students' learning of scientific concepts and principles.

The historical root of metacognition

Metacognition, as a target of study, originated after 1970 when researchers began to give more emphasis to essential knowledge and the

subject matter, as critical factors in learning. Children, as well as adults, were examined as they attempted to learn in semantically rich domains such as science concepts. With these shifts in emphasis regarding questions about the knowledge base, there was also another change from considering accumulation of facts and their reinforcement to considering restructuring of knowledge along with the compatibility of new information with prior experience as critical factors in mastering the subject matter (Brown et al., 1983).

This shift was accompanied by the formation of an uneasy alliance between developmental psychologists trained in the tradition of Neo-behaviorist learning theories and their descendants, information processing theory, and psychologists influenced by the traditional developmental school, such as Piaget and Werner (Brown et al., 1983).

One reason for the merger was methodological. Training studies were employed by psychologists from diverse backgrounds to address questions about the nature of developmental conceptual change. These provided a prime impetus to the growth of the concept of "metacognition."

The pioneer in this field was Flavell, a Piagetian theorist. Flavell and his colleagues (1970) became interested in children's awareness of their own thinking processes, memory, and the subject matter that influences learning. Following Flavell, Piaget and his colleagues (Inhedler 1974, Karmiloff-Smith 1975) became increasingly concerned with the self-regulation of learning.

Information processing theorists, (Brown, 1977, Simon and Simon, 1980, Case, 1974, Larkin, 1980) concentrated on issues of executive control. The executive is imbued with a wide range of overseeing functions, including predicting, monitoring, reality testing, and controlling deliberate strategies for learning. Both of these schools agree that the failure to learn and transfer failure in children and naive adults is due to the lack of declarative knowledge concerning the domain memory (Brown et al., 1983).

Toward the latter part of the 1970s, points of common interest shared between learning theorists and cognitive development were in answering the key question of how the children go from strict contextual binding to more powerful general laws. This section will address how both schools faced this question by examining the metaphors used by both schools to understand learning, the criteria they depended on to understand how the learner is able to transfer his knowledge, and the method used to illustrate the issues that underly "metacognition" as a field of study. This includes the types of knowledge that allow forming general laws, the process of going from naive learner to expert in transferring knowledge, and the strategy used by learners in forming theory.

The definition of metacognition

Piaget considered that the knowledge of one's own cognition is a necessary stage that would allow the restructuring of personal concepts and theories. This stage refers to the relatively stable, statable and late development information that human thinkers have about their own cognitive processes and those of others (Flavell and Wellman, 1977). This form of knowledge is relatively stable. One would expect that knowledge about a domain of knowledge would be a permanent fact about one's naive theory on the topic. This form of knowledge is often

statable-- one can reflect on the cognitive processes involved and discuss them with others. This type of knowledge is usually assumed to be late developing; it requires that learners step back and consider their own cognitive process as objects of thought and reflection (Brown et al., 1983).

Piagetians used the metaphor of the history of science to understand the way scientific theories were developed and generalized that to learners (Brown et al., 1983). It is thought that human thinkers subject their own thought processes to examination and treat their own thinking as an object of reflection. Similarly, learners regulate and refine their own actions. However, unlike behaviorists, Piagetians considered that though the refining of theories often happens in response to feedback concerning errors, it also happens often in the absence of such feedback. Indeed, even if the system with which one is experimenting is inadequate, active learners will improve their original production (Karmiloff-Smith, 1979). This means that a computer metaphor is not sufficient to explain the progressive way of inventing knowledge that Piagetians had suggested.

Piagetians considered that the beginning of conscious reflection occurs when the learner is capable of considering his/her actions and describes them to others, even though this may be done erroneously. Mature learners can create imaginary worlds and theories to explain actions and reactions within them. Such theories can be confirmed or refuted by means of further construction of mental tests or thought experiments that extend the limits of generality of the theory. This is

the essence of scientific reasoning and the end state for a Piagetian developmental progression of child as scientist (Brown et al., 1983).

Information processing theorists, however, used the word metacognition to mean the cluster of activities used to control the learning process. These processes include activities that take place prior to undertaking a problem, such as predicting outcomes, scheduling strategies, monitoring activities during learning, and checking outcomes. These activities are not necessarily statable and age independent. The information processing theorists reject the possibility of obtaining data about one's own thinking (statable knowledge). Erickson and Simon (1980) said "Can people have conscious access to their own cognition processes? Can they report on these processes, and how does the act of reporting influence the process of questioning?" They considered that this is not reliable, especially, as Brown put it, that Piaget himself said that people would be inconsistent in reporting what they saw, since perceptions are affected by their naive theory. These criticisms have little validity. This is similar to how Kuhn describes scientists' communication in different paradigms. Piagetians did not use self-reporting to obtain rich information about the differences between the experts and novices which is often the method often used by information processing theorists. The criteria for experts were derived from the philosophy and history of science. Piagetians wanted to see the compatibility between the process of acquiring knowledge in the history of science and self-reporting in children.

Information processing psychologists, deeply influenced by the memory model of Atkinson and Shiffren (1968) emphasized control process as a criteria for learning maturity. That is, strategies and routines for making more efficient use of a limited capacity information processing system (Campione and Brown, 1977). Case (1982) suggested that a person's total processing space is composed of space available for storing information, and space available for executing cognitive operations. Although total processing space is assumed to remain constant, as the concept develops, its two components are believed to fluctuate with a tradeoff executed between them. Thus, Case proposed that the important functional capacity that accompanies conceptual development, reflects the increases in storage space, which accompanies the decreasing amounts of operating space necessary for performance. The decrements in necessary operating space occur as a result of the growing speed, efficiency and automacity of basic processes and less attentional inference for rehearsal.

Currently there is a hot debate between advocates of information processing theory and Piagetian theory on this issue. The former consider that the constraints on what can be learned is due to memory processing limitation, while Piagetians feel that the limitation is in the apparatus of the children's inference (Carey, 1984).

Piagetian theorists considered that conscious inference is a later step in developing the theory in experts, while information processing theorists felt that as one becomes more expert in a specific domain, she/he would give less attentional inference to trade offs of more efficiency in rehearsing.

The question that arises from the information processing model is: can artificial intelligence account for all kinds of human intelligence (e.g., invention)? I think that artificial intelligence can account only for the use of information that is already discovered to allow for better judgement. Still, artificial intelligence cannot account for the types of intelligence that allow human beings to invent new knowledge. This means that the approach of the information processing theory restricts the criteria of expertise to such intelligence as memory capacity, amount of information in the memory, its efficient use, and organization of knowledge- types of knowledge which are accounted for in using computers as a metaphor.

Reorganization theory

Piagetian theorists (Inhedler et al., 1974, Karmiloff-Smith, 1979) presented classical papers (as acknowledged by such information processing theorists as Brown, 1983) on the mechanism of reorganizing theory. In this viewpoint, the basis for change is conflict (Inhedler, 1974). A serviceable hypothesis is maintained until an incompatible outcome ensues. Conflict generated by such inconsistencies leads to the formulation of a more powerful rule, to account for a greater range of specific experiences.

Inhedler considered that conflict caused by becoming aware of other phenomena, that are counter to other stable theories, would lead learners to form a more comprehensible, powerful theory. Piagetians felt that awareness of inconsistency in given information is a necessary stage to allow restructuring of the theory. Accommodation is a prior step to forming a stable theory (Brown et al., 1983).

Information processing theorists also acknowledged that conflict would lead to theory change. However, the process of change was some

the

prev

prob

acqu

phi

posi

bui

the

ind

min

can

car

be

two

ori

acq

the

inte

the

ste

thi

law

sha

something different. They considered that the primary step to changing the theory is induction. Inductions or generalization which counter the previous theory is the step for change. Newell and Simon's general problem solver model proposed the induction of scientific laws for the acquisition of the expertise of problem solving (Brown et al., 1983).

Piagetian advocates took their metaphor from the history and philosophy of science. Literature on the philosophy of science took the position that to build a scientific theory, the theory should first be built up by deductive reasoning, then generalization would follow, not the reverse. Medawar (1969) said that the chief weakness in using the induction method first is its failure to distinguish between the acts of mind involved in discovery and proof. Starting from a true premise we can determine and discover a theorem by reasoning which, if it has been carried out according to the rules, itself shows that the theorem must be true. Thinking that the process of induction could fulfill the same two functions (explanation and proof) is a mistake. For it is not the origin, but only the acceptance of a hypothesis that depends on the authority of logic. Believing that scientific discovery of the laws and theories turns upon the use of a method of induction would be an intellectually disabling belief if any one actually believed in it.

One example that emphasizes the Piagetian point, is that people "in the past" had implied knowledge about building huge geometric shapes such as pyramids and kaa'ba in old Egyptian and Babylonian civilization. This was before they became explicitly aware of how to invent a general law that would allow them to predict in advance how to build similar shapes (Fahl, 1966, Asimov 1982).

the

exp

ign

rai

pro

What often happens in teaching math and empirical science, is that the emphasis is to verify the scientific theory through mathematics or experimental conformation. Why and how this theory was first invented is ignored.

Systematic reconciliation of the theory

Inhedler (1974) and her colleague, Karmiloff-Smith (1974/ 1975) raised this issue (as cited in Brown et al., 1983) in describing the process used by the learner to restructure his theory:

> Learning within a domain follows a predictable sequence that is characterized by internal pressure to systemize and generalize knowledge. The student first works on developing an adequate partial theory for a problem. Typically, the student will develop several theories adequate for various parts of the problem space, each theory operating in isolation from the other. Once the problem space is functioning well, the student sets up and reconsiders the problem space metaprocedurally. Once students become aware of the discrepancies or contradictions resulting from the simultaneous existence of several partial theories, they begin attempts to reorder the differences and obvious contradictions. The students abandon the simple theories and reorganize the problem space, so that a single unified theory predominates. Only when the unifying theory was discovered, did the students return to perfect performance.... The construction of false theories or the over-generalization of limited ones are in effect productive processes. Over-generalization can be looked upon as the creative simplification of a problem. This is implicit in the students' behavior, but could be externalized in the scientists. Over generalization is not just a means to simplify, but also to unify. There is a general tendency to construct a powerful, yet often inappropriate hypothesis which learners try to verify, rather than refute. This temporarily blinds the learner to counter examples which should actually suffice to have them reject their hypothesis immediately. Progress comes only when the inadequate partial theory is well-established and the learner is free to attempt to extend the theory to other phenomenon. In this way, the theorists, be they students or scientists, are able to discover new properties that in turn make it possible for new theories to be constructed (p. 119, 120).

For Inhedler, the stage in which children use one powerful theory to solve problems does not come in one step. Rather, it follows a systematic path of reconciliation. The first step in forming the theory is covert implied knowledge. People do things because they know from their experience it works, but, as it happened in the history of science, when people try to understand how and why things work, their problems with misconceptions begin. After forming many partial theories, each of which worked well for one event, but which may have been incompatible with others, the unification process begins in which a more powerful theory is formed to explain many events related to the problem. At the end of this stage, children would be able to solve problems they face in everyday life, using one rather comprehensive theory. To form this comprehensive theory, students have to become procedurally aware of how their concepts had been developed through all the primary stages of forming the theory.

This implied that children would necessarily have several sophisticated naive theories through their efforts to formulate their theories from the phenomena. However, systematic reconciliation of many observations would lead to form one powerful theory. Primarily, learners begin to make conclusions without being aware of all the variables that allow them to make a more powerful theory. This systematic reconciliation leads the learner, at the final stage, to apply his knowledge and generalize it to solve any future problems using the one more powerful theory.

There was no effort by information processing theorists to show the systematic steps in the novice-expert shift. Carey (1984) criticized the methods used to differentiate between novice and experts, saying:

> Two different senses of restructuring are being contrasted (information processing theorists versus Piagetian). The first weaker sense can be thought of as a change from no theory to first theory. In thinking of restructuring in this sense, one concentrates one's research on aspects of the expert system, finding what the novice lacks. One notes that particular relations and abstract concepts are not represented by the novice, and that certain schemata are not available to organize the problem solving memory and induction inference. The second, stronger sense can be thought of as theory change. In considering the possibility of restructuring in this sense, one focuses not only on the alternative, but also the highly structured conceptual system of the novice. The acquisition of expertise by chess masters (Chi, 1982) is a good metaphor for the first sense of restructuring, but not for the second. Acquiring expertise in chess does not require abandoning a highly developed alternative theory of chess, while shift from Aristotelian to Galilean mechanics did (p. 7-8).

Carey gave an example of McClosky's work (1983) on restructuring in the stronger sense of ideas on motion. McClosky had demonstrated that the presence of advanced naive theory in the novice resembles the impetus theory in the history of science. She considered this demonstration valuable for science education. Similar restructuring by students was demonstrated by Nussbaum and Novak (1976).

Carey cited another example of the difference in systematic restructuring of knowledge between Piagetian and information processing theorists. In Inhedler and Piaget's version, the child is not credited with success unless he systematically discovers for himself the effect of all variables. Whereas, in Case's version, the experimenter structured the task, so the child considered only one variable at a time.

The process of induction would allow only the acceptance of the theory. This would not allow refutation of a "stable' theory to form another more advanced one. The method described by Inhedler and

Karmiloff-Smith has more potential in science education to explain the systematic stages in forming and restructuring the theory.

In supporting this view of systematic reconciliation and restructuring of theory as suggested by Piagetians, Carey said: "The history of science passes through a series of revolutionary constructions. Although a new idea has its own explanatory system, it depends on previous knowledge and data to prepare scientists to make another change." (1976). In her writing (1982), she cited Kuhn's (1977) position: "Over revolutionary time the unique advance of one generation has the potential to become critical environmental conditions for succeeding generations." Also in 1984, Carey, said one lesson from the history of science is that theory changes do not come easily; understanding how the explanatory system changed through different stages, in the history of science, would be of great help in similar restructuring by students.

In supporting this view in my dissertation I assumed that history of science can tell us under what conditions, and which prerequisite theory, allow changes. Several systematic observations, similar to the ones observed by scientists, could be used in the classroom.

<u>Type of concept to be imparted</u>

As I said earlier, an objective of information processing and Piagetian theorists is to explain the differences found between novices and experts in generalizing and applying their knowledge. Here also there is found differences between both approaches in illustrating the type of knowledge necessary to allow such generalization. For information processing theorists, acquiring knowledge about intelligent uses of information, in a specific domain of knowledge, could allow generalizing these strategies to many domains of knowledge. An example of that is Chi's, (1982), study in chess playing, and Larkin on the methods used in solving physics problems.

According to Carey, 1982, Piagetians did not consider that any kind of information would allow such generalization of knowledge. Piaget (1972) claimed that in the transition from Aristotelian mechanics to Galilean mechanics, scientists became explicitly aware of how their thinking about how things worked had changed. This type of knowledge requires students to deduce their theory from many premises. Carey (1982) said that understanding revolutionary concepts is needed to make steady steps in metaprocedural reorganization for students' theories.

Supporting Carey's view, I believe that studying the history of science would guide us in selecting which phenomena would be useful targets of investigations that lead to restructuring the general model that scientists accept. We could use a similar phenomena in the students' environment to restructure their theory. This type of knowledge has dual benefits. First, it would allow students to understand more about the scientific concept and use it to explain everyday phenomena (stable knowledge). Second, as students became aware of how their theory (or the scientist's theory) had changed and of all the different variables that had to be taken into consideration to produce such a powerful theory, this experience could enable them to generalize, and treat their process for understanding scientific concepts, or even everyday life problems, in the same way. This would allow students to understand precisely how scientific concepts were formed and restructured by scientists, not just as a general statement made in at the introduction of textbooks about the nature of acquisition of scientific concepts, but to engage in the same mechanisms as scientists (statable knowledge).

Kuhn's paradigm could be used to determine what proper questions the students should ask, what hypothesis should be entertained, and what relevant data need to be shown to make students accept the scientific theory. Carey (1982) claimed that students' awareness of how their scientific concepts about the revolutionary type of science developed could affect their learning and thinking in another domain. Basic understanding of revolutionary types of science cut through many domains of knowledge.

<u>Metaprocedural reorganization and students' learning</u>

Metacognition in the Piagetian sense was adopted by the study to understand scientific learning. When students read the textbook, they know on the surface level how to solve problems and give correct answers to specific questions that involve description (e.g., what) regarding phenomena. However, if we try to modify the problem, or to ask them "how and why" questions, which means asking them to formulate a theory and rationalize the events they describe, they give an answer which reflects their misconceptions. These explanations might be similar to the scientists in the history of science. Students' naive theories would change according to the environmental experience they became aware of and its incompatibility with their primary theories. This would lead to restructuring of their theories. These explanations (the bottom of the U shape in Fig 1) deviate more and more from acceptable scientific information. At the primary stage, the explanation could still be weaker and more naive than the students' initial implied knowledge. According to Piagetians, students tried first to stabilize their explanation, according to their primary partial theories, which would even blind them to other observations which contradict the early ones. When reaching the cognitive stage of being aware of how different partial theories contradict each other, the learner actively engages in reflective thinking to generate a powerful coherent theory to dissolve all the discrepancies, in the same way as scientists do, to reach the ultimate goal in the upper right corner of the U shape (see Fig. 1). Students would produce the right prediction and reasoning for the phenomena, not just memorize scientific information that could result in misconceptions.

Metaprocedural reorganization and instruction

Carey, Gelman and many cognitive theorists do not agree with Piagetian theorists that the complete unification process, used to reach present scientific theory can be achieved solely by students' natural inference, even for those who reached formal operational stage in their cognitive development. In the history of science, the more advanced theories were achieved after long periods of time, which means that simple cognitive development did not guarantee that the same process would repeated by simple natural inference.

According to the Vygotsky theory, the social cultural factors had a big role in this process. This signifies the problem of strategies used in instruction to make students comprehend the revolutionary scientific theories. Vygotsky's theory about internalization has the potential to understand the transference of other awareness to self awareness.

Here also information processing theorists tried to incorporate what had been suggested by Vygotsky into their approach (Paris, 1984). This would disturb the theory of Vygotsky. Vygotsky's approach is not just a copy of their computer model for instruction. In the computer, the branching path is already determined in the mind of the programmer. However, Vygotsky's approach is didactic. The instructor would change the type of stimuli depending upon the kind of feedback from students. This feedback could not be predetermined, since no one can predetermine what produces the internalization of a student's own thinking with that of the instructor.

In Vygotsky's approach, a great deal of learning occurs in the presence of, and is fostered, by the activity of others. Supportive others, such as parents, teachers, peers, and so on, guide a novice to mastery, and Vygotsky considered that there is a systematic dialectic process in how this guidance works. Vygotsky (1978) argues that all psychological processes are initially shared socially between people, particularly between child and adult, and that the basic intrapersonal nature of thought is transformed through experience to an intrapersonal process. Thus, for Vygotsky, the fundamental process of development is the gradual internalization and personalization of what was originally a social activity. Mature reasoners become capable of providing a supportive role, through the process of internalization.

Vygotsky's theory was adopted to understand the effective instruction (scaffolding) to cover the lack of social factor in

Piagetian theory. However, Piagetian understanding of the way students' theories are formulated is currently adopted to understand the process of learning (Brown et al., 1983).

According to Vygotsky's theory, mature reasoners who become aware of the different restructuring stages they passed through to learn a specific issue could help students engage in effective didactic dialogue, using reasoning to reach acceptable scientific theory (intervention).

The approach used by this dissertation integrates both Vygotsky's and Piaget's approach. Students' reasoning about the phenomena reflect their entry-level conception which can vary from one student to another, even in the same mental developmental stage, depending on whether the students acquire the prior information that is necessary to restructure their theories. Carey contends that if the necessary information was not available in the social cultural environment, then the students would never reach this unified operational stage in learning science.

Carey (1984) considered that Kuhn's paradigm could be used to determine what questions would be asked about the phenomena; what hypothesis to propose; what rational conclusion can be expected to explain the phenomena observed in everyday situations as we watch the process of scientific learning by students. Through this process, students become aware of how new explanations differ from their naive hypotheses. They follow the same path scientists used to restructure their theories and have greater power to explain a given phenomena.

The most important evidence in empirical research that supports Piagetian claims about the process of acquiring knowledge, is the presence of misconceptions incompatible to the scientific theory in students' explanations for everyday phenomena. Piagetians were the first to point out this phenomena in their explanation of metaconceptual knowledge. However, many writers in science education adopted the same phenomena that Piagetians spoke about and tried to treat that by the methods suggested by information processing theorists. An example of that is the work of Champagne, Klopfer and Gunstone (1982), who applied the theory and empirical findings of an information processing model. The first component of this model is a comparative analysis of the cognitive states (i.e. problem solving strategies and schemata) of uninstructed students, novices, and experts for a given topic area. They identified a number of dimensions which characterize the conceptual structure, such as the degree to which the propositions agree with accepted scientific knowledge. The second component of their analysis consists of the specification of instructional objectives and strategies based upon the above cognitive analysis. When reduced to the level of teaching, they engaged students in Socratic-type dialogues, as suggested by Piagetians, in order to arrive at explicit responses to a series of the problem statements. The teacher then provided the expert's analysis of the problems and asked the students to analyse their own solutions in the light of the expert's solution. Champagne, Gunstone and Klopfer (1983) had tried this method on mechanics problems. They discerned no appreciable differences between the pre- and post-instruction cognitive states for a group of academically-gifted, middle school students. However, there was some limited success with a group of university graduates enrolled in a teacher training program.

tec

the

an

pa

th

de

di

Th

fr

wh

an

Po

su

wo

Driver and Erickson (1983) had an objection to this earlier technique. They said,

> We suggest that such approaches to documenting conceptual structure may be useful tools in learning and to encourage students to make connections in a complex field of knowledge. However, since the knowledge structure had been identified using verbal methods with little reference to the phenomena, it is possible that students' meaning may be misinterpreted. This is a particular problem with younger children whose meanings and language capabilities may differ significantly from those of adults. In addition such an espoused knowledge structure gives little information about the way a student conceptualizes and responds to specific events and phenomena. It is well known that students may develop conceptual structure as a result of instruction and other experiences which can be internally consistent and quite elaborate (e.g., a model of atoms) but they do not necessarily relate these to actual phenomena... These methods could document complex ideas and relationships, without documenting the ways students use this knowledge structure in practical situations (p. 43-45).

Other methods of intervention are the ones which follow the theoretical orientation of Piaget. This method was reported by Nussbaum and Novick (1981) who attempted to shift students' understanding of the particulate nature of matter by encouraging them to expose explicitly their ideas about some events and then create class debates and demonstrations to reach an acceptable model of structure through class discussions. The results of this study on cognitive conflict are mixed. There do appear to be genuine shifts in some aspects of the students' framework. However, there is also evidence of a number of student ideas which remain resistant to this type of instructional strategy (Driver and Erickson, 1982).

Another Piagetian method of intervention is the one suggested by Posner, Strike, Hewson, and Gertzog (1982). This approach draws from the current work on the philosophy of science (Kuhn 1970, 1977), and the work of Piaget on causality (1974). In this strategy, students were led to make judgements on the basis of the available evidence. Their approach differs from Nussbaum in that they emphasize the type of alternative conception that students should acquire. Students in this approach would comprehend the idea to be considered intelligible and plausible (not just plausible, as in Nussbaum approach). Posner believed that Kuhn's paradigm could be used to determine the condition most suitable in making students consider the alternative conception. In focusing on the latter phase, they identified a number of conditions which permit a priori predictions to be made about whether new knowledge is reconcilable or not with existing knowledge. These conditions were identified:

1- Anomalies. The failure of the previous idea is an important factor for its successor.

2- Analogies and metaphors. These can serve to suggest new ideas and to make them intelligible.

3- Epistemological commitment. Most fields have some subject matter-specific views concerning what counts as a successful explanation in the field.

4- Metaphysical beliefs and concepts.

a- Beliefs about science; concerning the extent of orderliness symmetry, or non randomness of the universe are often important in scientific work and can result in epistemological views, which in turn can select or reject particular kinds of explanation. Such beliefs played a large role in Einstein's thought.

b- Metaphysical beliefs of science; specific scientific concepts often have a metaphysical quality in that they are beliefs about the ultimate nature of the universe and are immune from direct empirical refutation. A belief in absolute space or time is an example (p. 215).

In Posner et al. (1982), metaphysical belief was explained as follows:

> Metaphysical beliefs and epistemological commitments form the basis on which judgements are made about new knowledge. Thus, a conceptual change will be rational to the extent that students have at their disposal the requisite standards of judgement necessary

re

of

ab

th

st

th

us

re

Th

th

co

as

an

st

ab

di

le

Fi

th

of

> for the change. ...Students without these commitments will have no rational basis for change. Faced with a situation in which they are to accept the theory, they will be forced to do so on nonrational bases, for example, because the book, or the instructor said so (p. 224).

Here Posner and his colleagues considered that the basic method necessary to overcome students' misconceptions is to make students aware of the incompatibility between their theory and metaphysical belief about the universe that characterized twentieth century revolutionary theories (e.g., relativity theory). However, they considered that students (at early stages of becoming consciously aware of how their theory had been constructed) do not have the ability to make judgements using abstract reasoning to justify adopting twentieth century revolutionary theories. In this case, Posner depended on the anomalies. The reason for this consideration appears to be that Posner considered that students, at an earlier stage, can become consciously aware of the contradictions between their explanation about two phenomena. However, using reflective abstract thinking to choose between theories is reached only at the ultimate operational stage.

After this review of approaches of theorists to understand students' learning, I will now discuss what writers in the field think about these approaches and then discuss the particular approach this dissertation used to overcome the difficulty that students face in learning the biochemical activity of the cell.

Evaluation

Earlier discussion shows how Piagetian and information processing theorists, with different philosophical approaches, treated the problem of reaching the mastery of learning. It is now necessary to address what effect the use of the same term "metacognition" by both schools had on developmental psychology as a field. Brown et al. (1983) said that the tendency to use the term with different meaning would lead to confusion. It used to refer to two distinct areas of research from quite different historical roots, namely knowledge about cognition (Piagetian theorists), and regulation of cognition (information processing theorists). Wellman (1983) referred to metacognition as a fuzzy concept. The term metacognition serves primarily to designate a complex of associated phenomena, which illustrates the loose confederation of topics included. Of some concern however, is whether the associated phenomena are linked closely enough to warrant the use of a single family name. Would it not be better, at this stage, to abandon the global term and work at the level of subordinate concepts? One suggestion by Brown is that the use of the term be limited to its original use, "knowledge about cognition," where knowledge is stable and statable, as used by Piagetian theorists. Process terms (used by information process theorists), such as planning ahead, monitoring, resource allocation, self questioning, self directing, would be used alone, without the addendum metacognition.

Another point raised by earlier discussion is what empirical evidence is there to support both philosophical approaches in interventional research. Here also is a great gap. Piagetian theorists do not consider interventional research in their approaches since their method is more explanatory than experimental. However, their proposition about the way students restructure their theory has great potential for interventional research in learning (Brown et al., 1983; Carey, 1982).

Piagetians have suggested that learning revolutionary types of concepts would affect the transferring of knowledge to another domain. Though Carey said that it remains to be demonstrated just how metaconceptual change affects learning in other domains. For example, how does having the concept of hypothesis and experimental confirmation available to a learner through his learning of one particular domain actually affect transferring reasoning in another domain of knowledge?

In addition to little data about how knowledge of cognition would affect students' learning in all domains of knowledge (statable knowledge), there is even less data about how acquiring information in a specific domain of knowledge, taking into account the basic knowledge base, would affect using this knowledge to explain everyday life phenomena (stable knowledge). Nussbaum and Posner tried to use Piagetian methods in teaching science, but their methods still do not precisely follow what Inhedler suggests- systematically restructuring of the theory in the same way it happened in the history of science.

For information processing theorists, the emphasis was mainly on strategic actions. Brown said there has been greater emphasis on strategic actions; and although all theorists agree on the importance of knowledge, it just recently became the subject of empirical investigation. Psychologists know little about the influence of knowledge-based factors and the terms such as "familiar setting," "ecological validity" need a great deal of unpacking. Although they acknowledge the difference in the knowledge base between experts and novices, the main study by researchers in both groups was on how the strategy used affected this knowledge base, not on how the knowledge base itself would account for such differences. Variations in performance, across ages, were attributed to factors other than variations in knowledge; for example, capacity, limitation, or study deficit.

Brown said that the field is still in the primary stage. The methods of conducting research depend on providing a rich and detailed description of the qualitative differences in both factual and strategic knowledge between novice and experts. Brown et al. (1983) and Carey (1984) both agree that the majority of data, to date, has been cross-sectional. The performance of groups of children, varying in age or level of expertise, is compared and contrasted. Even most longitudinal research has a surprisingly cross-sectional flavor, in that the tendency is to see frozen shots of behaviour taken at quite long intervals. Both approaches provide a picture of cognition as static rather than evolving. Brown et. al who are information processing theorists, said that when the main subsystems are better understood by obtaining rich information about the differences between experts and novice, metaprocedural reorganization may be possible. This would enable psychologists to concentrate not only on qualitative descriptions of the stages of expertise, but also to consider the transition phenomena that underlie the progression from beginning to experts. Understanding more about the mechanism that allows restructuring of the theory enables intervention research to be more possible. This also implies that a full understanding of the domain of metacognition will be attained.

Another gap Brown cited is that there are fewer data concerning learning strategies after the middle-grade school years. Little attention was paid to strategy, other than rehearsal, categorization, and elaboration (the interventional methods usually used by information processing theorists). Brown also acknowledged that there was more emphasis on correlational rather than on manipulative research. The majority of studies shared a concentration on product rather than on process. That is, the main focus was on outcome measures, such as test scores of students who do or do not use a certain strategy.

Theoretical approach used

This dissertation shared Posner's and Nussbaum's methods of intervention in using Piagetian strategy to make students comprehend the scientific subject matter. It was thought that students should use their own judgement on the scientific theory in order to be accepted. It differs however from earlier works in that the study used predetermined systematic linear steps of reasoning about the phenomena to be watched in students (U shape, as in Fig 1), following Inhedler and Karmiloff-Smith (1974, 1975) in metaprocedural reorganization.

I used the history of science to determine which concept had to be presented first to the students and the characteristics of this concept. My perspective was based on the assumption that what made people, throughout the history of science, believe in a naive theory regarding a given phenomena, would hold true for students today. This differs from what Posner's strategy implied. Posner tried to shorten the actual path that scientists pass through in the history of science by making students rely on their original, intuitive, implied knowledge (the first step in the U shape Fig 1) in accepting the scientific point of view.

Posner's strategy did not suggest watching the reformation of partial theories by students into a unified integrated theory.

This dissertation follows the suggestion of Brown et al. (1983) to use metaprocedural reorganization in science teaching. Also, it followed the answers of students systematically through all lessons of instruction, in addition to studying how students' knowledge base would affect such restructuring. The dissertation does not emphasize studying the strategy used by experts and novices in reading or in elaborating as elaborated by information processing theorists. It depended on examining how students consciously form a stable theory in the same way it happened in the history of science, to understand restructuring the theory.

Having this summary about the current state of the field, the detailed theoretical perspective used in the treatment will be discussed in the following section.

Part 2. Theoretical Perspective for Instruction

In this study, the history of science was used to identify the questions asked, the hypotheses and conclusions of the phenomena that were obtained about the revolutionary, scientific theories pertaining to the biochemical activity of the cell. Students were then engaged in didactic reasoning to help them reach the present scientific theory.

I hypothesized that with carefully chosen information that matched the observation and logic of scientists as they restructured scientific theory, students would comprehend the incompatibility between different partial theories formed from different observations and they would have the ability to unify separate inferences into one powerful, unified scientific theory to explain all their observations related to this scientific concept.

The treatment took the position that if theories in the history of science were built through the integration of many ideas, then accommodation in one step to see what naive ideas students lack that contemporary scientists have, and then try to challenge students' misconceptions is useless. We cannot challenge students' misconceptions if they do not see the relevance of the information because they lack the prerequisite theory. Students should have relevant prerequisite theories before trying to build new scientific ones. Students would first be asked to explain the phenomena. That explanation would depend on students' entry-level knowledge. According to Vygotsky's approach (Campione et al., 1984) students lack of essential entry level knowledge prevents them from comprehending new information since they would not see the relevance of the new information. This is similar to anemia, which in turn prevents a person from eating a sufficient amount of food, which leads to increased anemia. It would be the role of mature reasoners (the teacher in this case) to find this essential entry-level knowledge as a basis for helping students construct theories, following some of the same important logical hurdles that scientists overcame in reaching contemporary ideas.

Teachers often provide support for students through teaching how they learned the subject matter of science. How scientists learned and how they think (using similar events that students experience) would be a realistic metaprocedural model. Instruction would follow the experiences that scientists observed. However, it would need to derive from the same environment that students live in, and students would need guidance to follow a productive logical path.

The reality of this environmental experience provides an internal motivation for the learner and encourages him/her to think deeply and be consistent in explaining the phenomena that surrounds it. The purpose is not to study science by recalling facts that will be soon forgotten after exams and retain naive theories to explain the phenomena. Science should be something students live in and use as explanations for everyday experiences. This leads students to correct planning, avoids doing things on a random basis. Therefore, I hypothesized that teaching students to overcome the critical barrier of their common-sense misconceptions as described by Driver and Erickson (1983) would be possible if we use the history of science as a guide, knowing how it was possible for scientists to jump over these barriers too.

Part 3. Procedures for Teaching

In treatment, I followed the path that led to the development of theory in the history of science. I considered only the plausible explanations for the event, not what other naive theorists during the same period used to explain the same events. For example, there were two theories raised throughout the history of biology; vitalism and reductionism. Many natural scientists applied the laws of physics and chemistry to understand the process of life (reductionism). They hold a metaphysical belief that the physical laws which worked in nonliving objects would work in organisms too. This method of conducting research was applied in the history of science without the failure of the vitalism. A refutation of vitalism was not prerequisite to adopting reductionism as a method of investigation by many natural scientists. Vitalistic theory made a strict differentiation between the nature of organic and inorganic material, considering questions asked about the process of life as different from questions asked about non-living things. I thought that vitalistic thinking (if it was found to exist in students) would be altered when students saw that organic material is composed of nothing but carbon, oxygen, hydrogen and a small percentage of minerals, in which carbon atoms connect within each other by highly energetic bonds. As a result of this logic, I hypothesized that students would know that the laws applied in nature are the same laws applied inside living organisms, without going into philosophical discussions about vitalism with students.

Another example of the different ways of explaining the same event is Priestly's discovery that carbon dioxide was used by plants, and released by animals, while the opposite happened to oxygen. Priestly considered the carbon dioxide used in plant breathing the same as oxygen used in animals. Lavoisier had a different explanation for this phenomena; his commitment to conserving matter allowed him to come to a stronger conclusion; by burning oil, the same materials absorbed by the plants (carbon dioxide and water) are released. This suggests that carbon dioxide is not used for plant breathing, but instead forms a plant body to be burned again through respiration.

In the treatment, I did <u>not tell</u> the students that Priestly explained his observations as breathing, and this is wrong. I directly encouraged the students to build the right structure so the phenomena could be better explained, following Lavoisier. I did not interrupt the logical flow of instruction to see if the students held other alternatives.

Listed below are the systematic steps applied in the treatment:

First, assuming the students would begin by having a correct implicit entry level knowledge (as was the case in the middle ages), they would say that water, soil, air and sun are essential for the life of living organisms.

Van Helmont's experiment was the first discussed. He concluded that water is the main source of food for the plants since the weight of soil changes only a little due to plant growth. If this idea depended on scientists' entry level knowledge, I assumed it would be unrealistic to ask more than this from students who began with similar naive ideas. The teacher should be aware of what the results of experiments could, at most, lead the student to discover. The teacher should not expect too much. Students' hypotheses that water is a source of food is more than enough at this stage. However, if students' answers were far from this conclusion, and their answers were inconsistent with what the results of the experiment should logically lead them to discover, then the teacher could lead them to a rational path for explaining the results.

Another observation might lead students to form a unified theory from several partial theories, by making them aware of the fact that by burning plant tissue, carbon dioxide and water are released. This could lead students to form one equation that would resolve previous contradictions. These are the key points that allowed scientists to form their theory in the early 19th century.

After the principle of conservation of matter was introduced, the conservation of energy was introduced. Students became aware of the importance of light in plant growth. They also become aware of how animals need energy to perform their general biochemical activities and maintain a steady _in vivo_ temperature. Thus students would comprehend that animals consume the energy that the plant first absorbs from the sun.

Following this, concepts about the importance of soil in plant growth, the mechanism of respiration, and the concept of DNA were introduced. Earlier theory formation could lead students to think that the body is composed just from hydrocarbon compounds, with soil having no role to play. Students would move then to form a more coherent theory, to notice that if we plant the same crop, time after time, in the same plot, the soil would then no longer be as good to the crops. Leibeg's explanation would then be introduced: the organism's body needs some minerals from the soil beside carbon dioxide and water. Decomposing the bodies' tissues and reanalyzing their components would give an idea about the components, kinds, and percentages of minerals in different plant and animal species.

Still the earlier conceptualization could leave students thinking that respiration is just another kind of burning which happened in a specific place, mostly the lung, the place where students learn that oxygen goes to. Bernard's observation would then be introduced to make students form a still more powerful theory. The blood stream that is full with digested organic molecules goes to every cell, not just to the lung, after leaving the liver. Here students would understand that oxidation of organic compounds happened in every cell, the body works in a coherent way, and the nervous system controls all the process.

This earlier conceptualization still lacks the explanation for the low, regular, and steady releasing of heat through respiration. The chemical concepts of transferring and conserving of energy through the regulation of coenzymes and ATP would then be introduced. This also would explain the essential needs for minerals for the body, since the protein of enzymes and the ATP contains many earthy minerals such as nitrate, phosphate and sulfur.

All these explanations are still missing a central linkage to explain the biological phenomena; the secret of variations among species in feeding habits. The recent findings in genetics would then be integrated to the recent findings about the biochemical activity of the cell. DNA controls what kinds of enzymes are to be produced. This means controlling the type of organic compounds to be synthesized by the body, and the type of organic and inorganic compounds that need to be made available to plants from outside.

In planning these lessons, I assumed that even if students were not active participants in this sequence of ideas, they would still be able to understand the logic which they portray.

All these concepts are introduced to the students in order for them to a) develop an integrated understanding of key scientific concepts and b) to relate scientific concepts to everyday biological phenomena.

These early discussions show that I took my perspective from Piagetian theory regarding efforts to help students become consciously aware of how scientific knowledge about the phenomena around was constructed by scientists. Moreover, it was my assumption that the conceptual difficulties which scientists had in formulating these theories are similar to conceptual difficulties students have in comprehending them. Therefore, it is important to know if there's any evidence in empirical research that reveals these similarities between students and scientists of past centuries. The next section will review some empirical research that shows a similarity between naive ideas held by students and scientists. The study tries to investigate the historical reasons for such a similarity.

Part 4. Research on Students' Paradigms

This section examines the evidence about concepts students hold about natural phenomena and the interconnections between them pertaining to a) dynamics and the universe and b) the biochemical activity of the cell. Discussion will focus on the evidence showing similarities between restructuring of theory, both in the history of science and among students.

Historical naive ideas about dynamics

There are a growing number of research studies that show the resemblance of students' misconceptions today to naive ideas in the history of science.

I will first explain Aristotle's view on motion, then the way this theory had been restructured in the history of science. This will be related to what the research shows regarding students' misconceptions:

Aristotle said that every object needs a force to keep it in motion. However, Galileo predicted that the natural way (ignoring the friction factor) is that every object will continue to move in a circular direction without force. His reasoning was derived from his understanding of the movements of planets as suggested by Copernicus. His thinking also was affected by the impetus theory of the medieval ages. The impetus theory claimed that an object set in motion acquires an impetus that serves to maintain the motion in curves (Asimov, 1982). Newton, however, recognized what Galileo had ignored, that the need of force to keep objects in motion on the earth, is the presence of resistant forces. Newton recognized that the natural direction of objects in motion is a straight line, an orbital motion in space is due to gravity, in which the lighter object moves around the heavier one as in the case for planets and stars (Geire 1984). It is conjectured that if Galileo had not been aware of the work of Copernicus in the first place, he may not have made his inference about spontaneous orbital motion, and if Newton was not aware of Galileo's reasoning about the spontaneous motion of the stars, he may not have produced his dynamics' principle (Asimov, 1982).

Students' misconception about dynamics

In school, students read about Newton, memorize his principles, and solve problems about force, without clearly understanding what these principles try to explain. The first evidence of this is Minstrell's

(1984) work with high school students. Minstrell asked his students the reason why a small-wheeled cart rolled across a smooth table top when it is pushed? Students correctly answered that a force from the hand is greater than a force resisting motion. But, when the students were asked what would happen if the friction force was reduced, many thought that the same hand force would still be required upon the object to keep it in motion. This concept clearly contradicts Newton's Law. Those students still held the Aristotelian idea about motion- that there should be force to keep an object in motion. Their ideas were less advanced than the medieval impetus theory.

The second evidence is the similarity between the advanced naive idea in the history of science, using the example of the impetus theory and the students' idea. An example is the McClosky study, (1983). McClosky asked college students what would happen if the string of a whirling ball suddenly broke (ignoring air resistance). Only 53% of the students predicted that the ball would travel straight forward as it fell. More specifically, a curved path was shown by 49% of students with no formal instruction, 34% who had taken one high school physics course, and 14% who had completed one or more college course (McClosky, 1983).

This means that a large number of students at this level have a more advanced but still naive idea that the object will still move in a curved direction as described in the medieval impetus theory, even after instruction on the topic. Thus, these studies on students' misconceptions in physical science illustrates similarity of contemporary students' ideas to those held by scientists in earlier times.

The theoretical development of the biochemical activity of the cell

As Kuhn mentioned, this topic developed through the integration of many ideas in biology, physics and chemistry (Kuhn, 1970, p. 15).

This topic passes through different stages:

First Paradigm: Understanding of this topic generates primarily from a metaphysical belief: those forces found to work on the outside (invitro) are the same found to act inside living organisms (reductionism).

Anaxagoras (c. 499-428) suggested that our body matter comes from the particles or seeds found in infinite space, and at death they resolve back into particle form (Asimov, 1982). This notion was refuted by Aristotle who was a vitalist. His ideas were the basis of the vitalist physiology that was still in existence in the Nineteenth Century. Vitalists regarded living organisms in a special way- not subject to complete mechanical analysis (Gordner, 1972, Mayr, 1982).

The middle ages could be considered as a transition period between the old vitalistic Aristotelian ideas and the new reductionism (affected by Descartes in the sixteenth century). Scientists in the middle ages were affected by their theory about the four magical substances of alchemy (soil, air, water, fire). People knew from their observations that the environment (soil, light and water) is important to the plants and that the air, plants, water and sun is important to animals. In the medieval ages, everything, including human attitude, was explained by these elements. If someone thought wisely, then a soil, non-rushing, element, dominated his body. If someone got angry quickly, then a fire element dominated him. If someone tended to do things according to what he liked, not according to what should be, then the air element dominated him. If someone tended to be inconsistent, then the water element dominated him (Ben Arabi, 14th century). Although alchemy is gone, these terms are still used in the Arabic vocabulary to describe people's behavior.

Second Paradigm: Descartes, in the 16th century, introduced reductionism to biological inquiry by suggesting that the method of inquiry used in physical science should be applied to biological phenomena (reductionism) (Mazlo, 1967). His suggestion was carried on by Van Helmont (1580-1635), from Brussels, who was influenced by alchemy theory. Van Helmont could be considered the father of biochemistry (Asimov, 1982). He used quantitative methods to understand plant nourishment and modified the four magical elements of the alchemy theory to conclude that water, in particular, is the basic element of the universe. His experiment proved that plants take only around 0.1% of their weight from the soil. He incorrectly deduced however, that "water was converted by the tree into its own substance." This conclusion was drawn from his belief in spontaneous generation (the development of living organisms from nonliving surroundings). Van Helmont was the first to notice that air is released by burning wood (carbon dioxide). Ironically, it is this gas, not water, that is plant life's chief source of nourishment, and Van Helmont, in interpreting his experiment with the willow tree, had neglected to consider the air that surrounded it. He had the right answer in the substance that he himself discovered, but he did not know it (Asimov, 1982).

Another theory was developed regarding the need for air for breathing. Malpighi discovered that air is used in the lungs, and that plants also need air for breathing (Asimov, 1982).

Hales discovered that more water is transported in plants when they have leaves, than when the leaves have been shed. This suggested to him that the air and the water entered to form the plant body. Thus, he offered a more complete comprehensive theory than Van Helmont. He also was the first to measure blood pressure (Bodenheimer, 1958).

This work was followed by the work of Priestly, who was affected by the alchemy theory and modified it into phlogiston theory. Priestly found that plants absorb what he called phlogiston (carbon dioxide), making the air more pleasant for respiration in animals (Bodenheimer, 1958). Priestly's discovery itself was important, but his conclusion was wrong. He thought carbon dioxide was used in plant respiration, in the same way that dephogisticated air (oxygen) is important in animal respirations (Conant, 1966).

Although the results of all these experiments led to the conclusion that plants absorb water and carbon dioxide to form a plant body (since these gases are released by the burning of plant tissues), most of these scientists did not come to this conclusion. Van Helmont concluded that only water forms a body's tissues. Priestly and Maplpighi thought carbon dioxide was used for plant breathing. Hales deduced that plants used air and water to build its body, his explanation was not accepted at that time.

The secret of this ambiguous conclusion lies in the fact that chemistry was still not developed at that time. The four magic alchemy elements, from which Van Helmont's theory and Priestly's theory about phlogiston were generated, was the guide to explain scientists' research. People, at that time, thought of heat as a fluid substance with its own weight just like carbon dioxide (Lanham, 1968). Scientists maintained vitalistic thinking about the need for organic material such as fertilizers. People felt that plants added something (vital) to the soil (Magner, 1974).

Third Paradigm: Lavoisier could be considered the founder of modern chemistry. He understood the work of Priestly, and integrated that with the work of Hales and Van Helmont to deduce that water combines with carbon dioxide to form what he called the oil of the plant (which was used in lighting at that time). The reverse happened in animals; animals burned food to produce heat through respiration which is another form of burning.

Still Lavoisier, who was influenced by widely held theory, considered heat as a fluid particle. He is the one who stipulated the term "calorie" to measure such fluid (Asimov, 1982). As it turned out, the whole tangle that centered around the problems of oxygen, combustion, and respiration could not be straightened out on purely chemical grounds. What was needed was the same sort of clarification that had been used in physics with the concept of force. This was provided by the work of Benjamin Thompson (alias Count Rumford) who was able to define heat as a form of energy which is weightless, rather than a chemical substance (Lanham, 1968).

Another fundamental misconception still persisted, even with this discovery. Scientists at that time did not know the source of heat that is produced through burning and respiration. Although they noticed that the procedure in which carbon dioxide combined with water to produce glucose (photosynthesis) happens only in the presence of light, they did not know the function of light. They thought that plants had secret vital forces, to make food by creating energy from unknown sources in which this energy was released by burning (Asimov, 1982). Biologists stipulated a new meaning for food; it became the material that produces energy from unknown resources and this is what they mean by the statement "plants make their food by themselves."

What helped in the acceptance of this idea in the Nineteenth Century, was that organic matter was a mystery; nothing was known about it, except that it contained carbon and other elements absorbed by the plant. However, when scientist attempted to find out what chemical compounds constituted the tissue of plants and animals, the situation turned out to be quite different. One of the chemical differences observed was that compounds in living organisms do not seem to obey the law of combination by weight in definite proportion. This law was a cornerstone for the atomic theory of matter. So, scientists placed a big barrier of differentiation between organic matter and non-organic matter (Asimov, 1964, Lanham, 1968).

Liebeg, and other scientists in that period, believed that animals used food stuffs synthesized by plants to support combustion, which supposedly took place either in the blood or the lungs. Liebeg believed that only green plants could build up complicated organic substances from the simple inorganic elements they took from the air and the soil. He pointed out that plants took other things from the soil, not just water, as considered earlier. He considered plants as synthetic chemical factories. Animals were degradative chemical processors (engaged only in catabolism), taking the components they needed for their tissues from plants and used the rest for fuel (Magner, 1979). The great amount of information gathered by those scientists during the 17th, 18th, and 19th centuries was being interpreted in terms of function, although this function was largely seen as a matter of mechanical engineering (Lanham, 1968).

There is another point that needs to be clarified, however. Anyone who examines the names of those scientists will quickly discover that most of those names were connected to the history of chemistry, rather than biology. What were the biologists doing then? As mentioned earlier, Aristotle considered that questions asked about biology were different from questions asked about nature, while some physical scientists, such as Van Helmont, Priestly, Lavoisier, and Liebeg followed the questions and methods of physical science to produce information which were reductionist in character. The biologists, on the other hand, considered questions asked about biology as explanatory, pertaining to natural history. They worked on the problems of the classification of species and of adaptation (Mayr, 1982).

An example of such isolated conceptualization between the work of physical scientists and biologists can be illustrated by Schielden, a biologist, in developing the cell theory, "plant grows as it produces its number of allotted cells." However Schielden had misconceptions, believing that plant growth resulted from an aggregate of fully individualized, independent separate beings, including the cells themselves (Lanham, 1968). The biochemists, at that time, came to the conclusion that leaves are the place for manufacturing glucose. What must be pointed out though is that if Schielden really integrated what biochemists at that time were working on with his work, then it would be logical to say that the cell would not have an independent life. Rationally the cell could not get its nutrition if it has an independent life from other cells in the leaves, from which the major source of nutrition comes. These questions were not answered by biologists who held vitalistic thinking and who worked independently from physical scientists.

Fourth Paradigm The work of Bernard and his student Pasteur, revolutionized the way people understand this issue. Bernard set a new way of understanding living organisms, which was later called "homeostasis," by Cannon. The coordinated physiological process which maintains the steady state of the living organism, is so complex and so peculiar to life, it requires that the brain, nerves, heart, lungs, kidneys and spleen, all work in union. According to this paradigm, animals are not just consumers; an animal's body is able to change protein into glucose. The process of metabolizing is not just for burning organic stuffs, as in machines. The process is controlled by the brain and happens in every cell. Animals are able to engage in both anabolism and catabolism (degradation and recombining of food molecules) (Lanham, 1968). Bernard and Pasteur were a good deal ahead of their time since functional biochemistry, at the intercellular level, did not really gain momentum until well into the twentieth century (Magner, 1974).

The work of Bernard was not easily accepted by scientists who believed in spontaneous generation, which assumed that the cells could be produced from inorganic material, but did not alter chemical substance. This implied that they also believed the processes of photosynthesis and respiration happened outside the cells.

There was a long battle between Pasteur, who was originally a chemist, and biologists to prove that respiration happened because of a process that occurred inside the living cell. To prove it, Pasteur first proved that the fermentation process happened because of the work of microorganisms, while biologists of that time believed that fermentation was evidence that respiration did not happen because of the cells' activity. Through his work, Pasteur set aside the idea of spontaneous generation and established a new theory of disease (Lanham, 1968).

As pointed out earlier, vitalistic thinking was maintained due to the scientists' failure to explain the secret source of energy that is generated through burning the tissues of living organisms. Mayr, in the middle of the 19th century, questioned scientists' belief that plant synthesized energy by itself, (no outside resources), saying "The creation of a physical force, of itself hardly thinkable, seems all the more paradoxical when we consider that it is only by the help of the sun's rays that the plants perform their work." (Bodenheimer, 1958, p. 394). Mayr was considered the first scientist who believed in conserving energy.

Mayr was well ahead of his time. Confirmation of his revolutionary idea was difficult, since radioactivity was the only way to verify such theorization, and vitalism was the predominant way of explaining life's processes. Mayr's point of view was ignored during his life time, and he ended up in a mental hospital where he died early (Bodenheimer, 1958).

Mayr and Bernard's theorization was not accepted until the early twentieth century. Vitalist who considered the autonomous characteristics of biology as a field, and reductionists, who considered all the problems of biology to be explained by physical science, continued to battle each other through the 19th century. In the twentieth century, accumulated evidence, made possible by better technology, allowed people to appreciate what those great scientists in the latter half of the 19th century stood for. The detailed chemical structure of protein and DNA were discovered. Also, it was learned that chemical processes in cells were controlled by enzymes. It was recognized that all manifestations of development and life are controlled by genetic programs. DNA controls what kind of food is eaten and what type of interchangeable parts are synthesized, since it controls what type of specific enzymes are to be produced (Mayr, 1982, Asimov, 1984). In the sixties, some biochemists still had not abandoned hope in finding some evidence for the theory of spontaneous generation. Sagan and other scientists put tremendous effort into synthesizing nucleic acids inside the lab. Their works failed. The secret was later discovered by the work of Baltimore (1975), through working on cancer cells. He found that DNA itself was produced by specific enzymes. It is cyclic: the DNA controls the production of enzymes, and the enzymes control the production of DNA. Baltimore received the Nobel prize in physiology in 1975 for this work (Asimov, 1984). Genetic engineers are currently engaged in using the enzymes that control the work of DNA to cut its chain at certain points, recombining them in different ways.

As explained earlier, the discovery of the function of DNA voids any rationale to divide biology into two fields. It provided a unifying theme for biology which permits both the study within the cell and understanding of species' organization.

Biology textbook conceptualization

Earlier discussions provided a clue for the way biology textbooks conceptualize biological information. The lack of a unified, coherent philosophical approach to define biology as a field had its impact on current school textbooks. An example of that is the suggestion of Schwab that the questions asked by biologists are different from those asked by chemists or physics. He stated that biology and the physical sciences "...differ in methods, in guiding conceptions, in the kind of knowledge produced, and in degree of certainty" (1964, p. 6). This means that Schwab encouraged separation, not integration, between the biology and physical science fields in school curriculum. Schwab claims that there is a difference in the degree of certainty between biology and physical science. However, when approaching biology from a molecular level, there is no difference in methods of investigation between biology and other physical sciences. Those who work in this field are mostly physical scientists. Moreover, the method used by Darwin should not be generalized to all fields of biology.

In textbooks now, students study about the biochemical activity of the cell as a physical and chemical process, without connecting it to the variance in species, ecosystem, and adaptation. Students study other sections about species, adaptation, and ecosystem, without connecting them to the biochemical process of organisms. Students find themselves in a dilemma, trying to put this information together in a logical way to come up with a scientific conclusion.

Textbooks maintain the old biochemical conceptualization afforded by the functional, mechanical theorists of the 19th century; the plant as producer and animals as consumers. Students must understand that food is the energy stored by the plant as hydrogen bonds. Textbooks afford the recent disciplinary knowledge in biochemistry (Kreb and Kelvin cycle), but still follow the conventional, separate 19th century conceptualizations about various biological fields such as genetics, adaptation, and species variation.

When presenting biological information, textbooks in Jordan, which also follow the conventional method of presenting biological information, include separate experiments in the history of science. The scientists' conclusion is presented, although it was not clear to the students how the conclusion of historical experiments was wrong and had been restructured. In Chapter 4 and 5, the effect of textbook presentation on students' understanding will be discussed.

<u>Research on students' understanding of the biochemical activity of the cell</u>

Research on students' misconceptions reveals the development of their understanding of the issues that underlie the biochemical activity of the cell follows a similar line discussed earlier, regarding this topic's development in the history of science.

First Paradigm. Soil was considered to attribute a considerable amount of plant weight. Wandersee (1983) in a cross age study and Smith et al. (1985) studying seventh grade students, found that some students believe the weight of a plant comes from the soil. This theory was more predominant among younger students (Wandersee).

Second Paradigm. Water as the source of weight. Plants have a vital force to produce organic material. Air is used for breathing in both plants and animals. This happens in lungs in animals. Light and heat are particles that correspond to the weight of the body. Plants add something vital to the soil.

Wandersee (1983) in a cross-age study and Smith et al. (1985), studying seventh grade students, found that some students believe that the weight of plant comes from water. Wandersee showed that more students in higher grades, tend to believe that a larger part of the weight comes from water instead of soil which is identical to the development of this concept in the history of science.

Research by Bishop et al. (1985) revealed that many students preparing to be elementary teachers, equated breathing and respiration, believing that both of them happen in the lungs. The research identified another related misconception. Students did not understand that the function of respiration is to produce energy in organisms. Research by Treagust (1985) on secondary school students identified another misconception: some students thought that in photosynthesis, carbon dioxide is used in plant breathing.

Research by Smith et al. (1985) showed that seventh grade students believed that loss of weight would be in the form of energy. Research by

Wandersee (1983) in a cross age study, showed that students, at a higher secondary level, tend to believe that the body of a plant comes from light. These results could be explained by the students' understanding of the metaphoric language which is used at higher grade levels, such as, "as plants grow and carry on photosynthesis, they store energy from sunlight."

Further, Wandersee (1983) in a cross-age study, found that students at lower grade levels tend to believe that the soil gained weight from the plants, which is a vitalistic and non-conservative mode of thinking.

Another sort of vitalistic thinking was evident in a study of seventh graders by Smith and Anderson (1986). The students made a strict differentiation between the waste of organic tissues and other types of materials, such as rocks, etc. Those students did not believe that organic material could be recycled in the form of inorganic material such as carbon, oxygen, and minerals. Dole and Smith (1988) identified fifth grade students who tend to believe, after instruction, that the growth of plants happened from cell division independent from outside resources.

Conclusion

Although one can deduce from the studies above that students' misconceptions, in principle, have many common aspects to those held by scientists in the history of science, it lacks many of the important elements that Brown et al. (1983) suggested for future research. All of these studies are snapshots. They were conducted in separate intervals. They are cross sectional, not longitudinal. Very few studies followed students' restructuring of their theory during instruction. Virtually no work has been done at the high school level, accompanying instruction to verify the nature of students restructuring of their "stable naive theory." For example, these studies did not show how students' understanding of photosynthesis would affect the level of their understanding in respiration or the function of soil. Besides, intervention research did not use the suggestion of learning theorists (Brown et al., 1983), to use metaprocedural reorganization to allow students to generalize their knowledge to everyday life situations. And although many interventions follow Piagetian lines in making students aware of the phenomena to challenge their misconception; these did not follow a systematic restructuring of the theory as originally suggested by Piagetian theorists.

This dissertation tries to verify the hypothesis proposed by Brown et al. (1983) that using metaprocedural reorganization in intervention research would allow better learning. It also follows their suggestion, and the one of Carey (1984) and Driver and Erickson (1983) to use longitudinal section in following students' answers during the time of instruction, to understand precisely how student restructuring of his theory would happen, and to see if it follows a systematic reconciliation and integration to many observations, as hypothesized by Piagetian theorists.

This dissertation follows Brown's suggestion in trying to understand the effect of such intervention in the conventional place of instruction- the classroom- and to study the type of reasoning given by students. The dissertation also investigates how the sociocultural experience, including previous learning that was a byproduct of instruction using the conventional curriculum, would affect such restructuring. This could provide a better understanding of how the integration of Piaget's and Vygotsky's theory would explain conceptual structure in students.

The previous research on this topic emphasized the characteristics of the learner and his/her entry level knowledge as a reason for unsuccessful learning. Anderson and Smith identified students' functional concepts as a barrier from understanding scientific concepts. This was done on students at younger ages. The naive ideas were from the primary type, in which functional knowledge of students was not what could be tested experimentally (e.g., soil as the source of a body's weight). Wandersee (1983) and Treagust and Haslam (1986) examined students at various developmental stages in which developmental levels would affect students' learning. None of these studies examined how sociocultural factors would work to stabilize students' naive theory.

Although the previous researches did not discuss how the sociocultural factors of students studying the formal school curriculum could enhance their naive ideas, the findings of the researchers could indicate that. For example, students are unlikely to speak spontaneously of cell division as a reason for growth, as in Dole and Smith's research (1988). This happened as a result of the less integrative curriculum. Students abandoned their old intuitive theory about what growth is, and replaced it with a vague idea about cells, without being taught that the cell itself contains the same material they see outside. When students begin to know and study that soil is composed from minerals, etc., and become aware of the types of reactions that such minerals engage in, but still do not know anything about the types of organic material inside the body, or its reactions or how it is decomposed, then students would differentiate between organic and inorganic material, thinking that organic material is from a source different from inorganic material formed outside living things.

Students' misconceptions in propositional knowledge were identified by researchers who tested students' understanding at higher grades, an example is the correlation found between students' naive idea that light is the source of weight at a higher stage (Wandersee, 1983) and introducing the function of energy with vague metaphoric expressions in the textbooks, at that higher level. Textbooks, at this stage, speak about the energy condensed in organic bonds to provide food, leading students to think of energy as particles (similar to early scientists who postulated this definition).

Evidence of vitalistic thinking in secondary school students was found by Treagust and Haslam (1986). Students believed the growth of plants comes from the plant itself, "from chlorophyl." Also at this stage, this misconception is more likely to be correlated with a secondary biology textbook's detailed description about what happens in the photosynthesis process, introducing technical words about the function of chlorophyl, to students who do not have enough information in chemistry and physics to understand this concept. Students learn in one section that cell division is responsible for plant growth, and in another section that chlorophyl works in photosynthesis. Students would be unlikely to understand the rule of chlorophyl in a less integrative curriculum. What they end their study with is that they think that the chlorophyl cell is the one responsible for plant growth.

The earlier researches did not test the presence or absence of both types of knowledge (proposotional and functional knowledge) in the same student. Although one could suggest that the ability of students to explain everyday biolgical phenomena in a scientific way would mean understanding the abstract conceptual structure to allow such generalization and vica-vesra, this was not tested empirically. Driver and Erickson (1983) suggested that experts have the ability to move between the theoretical and sensory domain and to bring proposotional knowledge to bear in practical situations. Further, Driver and Erickson suggested that in school science knowledge, this manifistication of individual conceptual framework may not necessarily be related. Students' responses may differ significantly depending on whether they are investigated using a technique which is conceptually framed, or one based on an actual event or phenomena.

To overcome students' misconceptions in explaining everyday biological phenomena, and to understand more about how the sociocultural factors, such as formal and informal learning, affects students' understanding, I arranged the instruction to follow the logical historical restructuring of scientific theory. I examined a) the effects of secondary school study of biology using this curriculum, b) the influence of the socoicultural factor, and c) an intervention, based on metaprocedural reorganization, and students' understanding of the biochemical activity of the cell. I asked this question: Do students' misconceptions happen just because they, as active learners, have formed them from everyday explanation of biological phenomena, or because past experience in instruction and curriculum have more impact in forming the same stable sophisticated theory, as proposed by Piagetian theorists? This question will be investigated by this study.

CHAPTER III

METHODOLOGY

The primary goal of this dissertation is to assess the uses of metaprocedural reorganization in the science class room. This method implies that students would unify their partial theories about the concepts that underlie the biochemical activity of the cell, in the same way scientists unified their own partial theories as they developed them. These powerful explanations have led to more precise predictions and eventually to further integration and stronger explanations that now form a wider, more comprehensive theory about phenomena in the natural world.

To test the effects of this method, the study investigated significant statistical differences between students in experimental and control groups. The study also examined whether students tend to form coherent theories about the issues that underlie the biochemical activity of the cell in the same way as scientists. The study also inquired into how this process may be affected by the sociocultural factors of the students' previous study through their school years.

In the sections that follow, the materials used in treatment, the samples, the methods of collecting data, and the methods of analysis will be presented.

Material

Textbook material

The textbook used in the study is the one prepared by the Jordanian Ministry of Education for eleventh grade. Material in the textbook specific to the treatment is found on pages 15-24, 72-75, 77-80, 83-90, 96-102 and 110-112. The textbook followed the conventional method of isolating conceptualization in different fields of biology (Mayr, 1982). The textbook focused its discussion on the mechanisms used to convert food into energy and to connect the function of photosynthesis to respiration. On page 15-24, the textbook addresses the structure of the organic compounds inside the body; carbohydrates (mono, di, and poly saccharides), proteins (Aminoacids, and Peptides), fats, nucleotides, and ATP. The textbook explained the issues under study by the following:

1- Photosynthesis: On pages 62-66, the textbook systematically presents the historical experiments in photosynthesis. The erroneous conclusions of Van Helmont and Priestly were presented, without telling the students that these conclusions were modified by later experiments. The recent facts about this issue followed, using chemical equations as an illustration. The textbook left it up to the students, who have no background in organic chemistry, to understand that the conclusions of earlier scientists contradict what is accepted in the twentieth century. Although the questions asked by 19th century scientists dealt with the function of soil and the ecosystem, this was not integrated to this topic.

Examples of textbook discussions follow:

After discussing the historical experiments, the textbook jumped to this conclusion on page 64:

> At the end of the 19th century, scientists proved that the green plant can change the solar energy into chemical energy, which is stored inside organic compounds.

In another part, page 66, an even more technical treatment is given:

> There are two chlorophyl diets in the plant which are responsible for activation of the electron through absorbing the infrared light. The first absorbed the wave length at 673 M,u, the other absorbed the wave length between 683-700 millimicrons.

2- Respiration: The second part of the material about function of respiration is addressed on pages 72-75, 77-80. On page 72, it is stated that:

> There is a special tissue in plants to store energy in the form of carbohydrates in roots and stems. By eating food, human beings get the energy that plastids have absorbed, while carbon dioxide and water return to the environment. The bonds between organic molecules contain the solar energy which is released again by cellular respiration. We can consider food as solar energy stored in a carbon bond, and it is a source of energy, like gasoline is to automobiles.

On page 74:

> All the material composed in the cells are energy resources, for it generates energy through its oxidation. Whenever energy transforms from one form to another, it is calculated by calories. A calorie is the quantity of heat that is needed to increase the temperature of one gm. of water by one degree centigrade.

At the bottom of page 79:

> In order to measure potential energy, we burn the food and measure the amount of calories released. For example, by burning 1 gm. from glucose , 3.8 calories would be released.

3- Respiration process and the work of enzymes and ATP: Pages 83-87 illustrated the historical development for the discovery of the respiration process. However, the conclusion of recent discoveries did not logically follow earlier discoveries. For example, the textbook points out that early scientists thought that respiration is a kind of burning. The textbook quickly followed that by illustrating respiration as burning, controlled by the work of enzymes. The textbook did not clarify why scientists considered enzymes to be responsible for controlling the respiration process. In the history of science, the function of enzymes was verified by Buchner's work. However, his work was found in another section called anaerobic respiration.

On p. 96-102, the history of discovery of enzymes in the history of science was presented, but still was not drived from the premises that are given. The textbook said, "Buchner discovered that fermentation happened when adding sugar to the yeast, which means that the yeast contains an enzyme." Analysis of the history of science showed that the yeast, per se, was not the phenomena that scientists targeted their question about, when they discovered the enzymes. The question behind the scientists work was to verify whether respiration happened because of the life spirit, or whether it was just a chemical activity that could be imitated invitro. For natural scientists, respiration is just a chemical reaction. It happens inside living organisms because of the presence of special catalysts (enzymes). Buchner's fundamental achievement revealed that fermentation (a type of respiration) occurred in the presence of dead yeast in a sugar solution, implying it is not "life" per se that allows respiration to happen, which was the vitalistic point, but it occurred due to the presence of catalysts called enzymes (Lanham, 1968).

This means that the significance of Buchner's work was not in discovering that by adding yeast to sugar, fermentation would happen. This point was made clear through the work of Pasteur long before Buchner's discovery. The fundamental point in Buchner's discovery is that the yeast was dead when fermentation occurred, meaning a catalyst (enzymes) was responsible for the process, not life per se. This lack of using sufficient evidence to reach scientific conclusions resulted because the textbook stated scientific facts, without relating them to the key question asked by scientists about phenomena. The scientists' fundamental question was: What made respiration a unique life process? In the textbooks, the phenomena of life and death was considered irrelevant contextualization. Thus the textbook erases the whole meaning of the scientific thinking process, turning it into just absolute facts.
4- The structure of DNA: In the Mid-Twentieth Century, scientists were looking for a connection between the work of enzymes and DNA, in order to rationalize the differences in feeding habits from one species to another. However, the textbook presented the recent fact about DNA without relating its function to explain everyday life phenomena. On pp. 110-112, the textbook discusses the structure of DNA and the procedure used to send the messages that build the enzymes' protein in the body. The textbook failed to connect DNA and the enzymes' work to show that variations of the DNA codes could lead to variation in the types of enzymes, in turn leading to a variation in feeding habits and the ability to adapt to environmental conditions.

Although the textbook presented new propositional facts about the biochemical activity of the cell that were discovered in the sixties, the conceptualization and classification of information followed the old 19th century conceptualization in biology, before new facts about the structure and the function of coenzymes and DNA were discovered. In early scientific conceptualization, the biochemical activity of the cell did not explain the classification of species or the adaptation problems; this was done using Darwin's theory. Although recent scientific discoveries in genetics could explain this more precisely and explicitly, these discoveries are still not used to explain this problem in the biology textbook.

The treatment material

The treatment tried to cover mislinkages in the presentation of the textbook, between the biochemical facts and the questions asked by scientists in the history of science about the phenomena that led to discovery of these facts. The treatment integrated many concepts that could be classified as irrelevant to the topic of the biochemical activity of the cell. The specific role of minerals (phosphate and nitrate) was integrated to the topic in the treatment, by showing students that without minerals, living organisms could not find the raw material to synthesize protein and nucleotides. By integrating the function of DNA to the function of enzymes in the treatment, the difference between species in adaptation and feeding habits was explained. The textbook just presented the specific role of DNA in building enzymes without connecting it to classification and adaptation. Also, the function of photosynthesis, as emphasized in the treatment, is to provide energy and interchangeable parts. The textbook defines the function of photosynthesis in building the body's tissues, in one statement, while the remainder of that chapter illustrates the function of photosynthesis as condensing energy. The word food, in the treatment, was not used to equal energy (as it was in the textbook). This kind of analogy was not used at all.

The treatment was designed to follow the logical restructuring of the theory in the history of science. Class discussion was directed towards considering the ideas that led to more scientific development, systematically following the path used in the history of science. For example, in the 19th century, there was a vitalistic school which considered that the questions asked in biology were different than those asked in natural science. They did not consider that natural laws could be observed in living organisms. During the same period, the reductionism school used natural laws to explain what happens inside the body. Discussions during the treatment emphasized the spirit that reductionists took in explaining their research. I did not address questions specifically designed to uncover vitalistic thinking, and I did not intend to trace the presence of such thinking at the time of discussion. Applying natural laws to explain vital activity in living organisms was used intuitively in the history of science, not because scientists were able to prove the failure of vitalism.

I hoped the logical flow of the lesson would correct other erroneous considerations. For example, carbon dioxide was considered by Hales as a gas used in building the body tissue, while Priestly considered it necessary only for plant breathing. My discussion was directed to the conclusion that carbon dioxide is used in building plant tissue. Accepting the notion of conserving matter and energy and differentiating between energy and particulate matter were prerequisite to understanding the issue of the biochemical activity of the cell. Still, this was not intended to be the core of discussion in the treatment. Planning the context of discussion with students was dependent on assuming these notions were already part of the students' thinking and there was no time arranged to develop this understanding.

The method of instruction was built systematically, according to the concepts and questions asked in the history of science, to allow students to develop their own inferences. I had arranged the topic about the biochemical activity of the cell in seven lessons, introducing the concepts systematically, following the same order of their discovery.

1- Forming organic compounds: Through photosynthesis, water combines with carbon dioxide to form glucose. This glucose in turn forms different organic compounds, like starch, cellulose, etc. This forms a considerable part of the body weight of plants, while other major parts come from water, used as a solvent for many compounds in the body.

2- Function of respiration: Through respiration, organisms return what had been absorbed by the plant-- carbon dioxide, water and energy. Every organism needs energy for its biochemical activity. This energy is released through respiration.

3- Function of soil: Organisms need slight quantities of minerals from the soil, such as nitrate to form protein and phosphate to form ATP. They need only a small amount, since ATP and coenzymes work cyclically, time after time.

4- Metabolism of protein: Proteins are metabolized in different ways, either producing glucose for respiration, or as "building" blocks in the development of body enzymes and other components that are needed in the cell.

5- Respiration mechanism: Respiration is a controlled burning that occurs in many steps through the work of coenzymes. The body is not just a machine. The burning does not happen in one particular place; it happens in every cell. The nervous system coordinates the whole process of metabolism.

6- Function of enzymes and ATP: The reason the respiratory process can go on continuously inside the body, while it will eventually stop outside the body, is the continuous circulation of ATP and enzymes. Inhibiting this circulation by preventing any particular coenzyme from completing the circle, would lead to death. This is what happens in poisoning. This is also why plants and animals only need a small amount of minerals from the soil, since these minerals are part of the co-enzymes. The same co-enzymes can be used over and over, but the eventual lack of "vitamins" for the body would lead to malnutrition and finally death.

7- Function of DNA: DNA controls the production of enzymes, which means controlling what kind of chemical reactions and what organic compounds the body is able to produce. Control of synthesizing organic compounds means control of what interchangeable parts the organism can produce and take in. It also dictates what antibodies the body can produce, which means controlling the degree of adaptation to environmental factors including diseases. This is why different kinds of organisms follow different feeding habits and why people differ in their ability to defend themselves under the same environmental conditions.

The questions and actions used to help students make inferences to reach the conceptual goal of the study are given in Appendix C.

Population

The study was done in a girls' public high school in a town twenty miles northwest of Amman. It is located in the middle of two old main roads that connect the north and middle part of the West Bank (Nablus and Jerusalem counties) with East Jordan. Most of the people there are descended from generations of townspeople. Although the people live in town, which affords all the services that modern cities could offer, they own agricultural land in the area that is borded by the Jordan Valley to the west, Amman to the south, the Baqa' valley to the east, and the Ajloun mountains to the north. Most of the people spend much of the summer months in these lands. This means a high percentage of the girls in this study were familiar with agricultural practices and plant growth, in addition to taking advantage of what the town offers in better learning opportunities.

The study was done in the main girls' high school. This school is the favorite for teachers and students given its location in the town's center. The students, average age sixteen, were in the eleventh grade science section.

No international exams were required to enter the advanced academic study in Jordan when this study took place. Although new educational policies have since been instituted, the only prerequisite was that students earn an average score of at least 50% in science and math subjects the prior year.

I assumed that students who were really weak in either math or science would not choose this section, for there is a complex, comprehensive national exam designed for students at the end of the twelfth grade.

Students at this level had previous knowledge of photosynthesis and respiration. Teaching these topics begins in elementary grades. They are also required to study chemistry, physics, and biology in their science program, beginning in the seventh grade with a general natural science course, separate biology and natural science in the tenth grade, and chemistry, physics and biology in the science section of the eleventh grade.

There were two sections of biology classes. I chose ten volunteer students from each section. Students were assigned to each section at the beginning of the school year. School administrators felt that both sections contained the same quality of students. Students with high, middle, and low averages, had been assigned equally to both sections.

Some of those students were taking private physics lessons from a public, nonprofit organization. This organization's prerequisite was that students should achieve at least an 80% average score in science.

The names of the students in both groups are listed below. An asterisk beside the name indicates a student who took private lessons.

Table I

Students' Sample

Experimental	Control
Abear*	Amal
Asma	Amena
Basema	Eman
Fatema	Fadwa*
Ghayda*	Hanan*
Khollowed	Kareama
Ohowed*	Rowla*
Sawsan*	Sameara
Salam*	Teghread
Sumayya	Wegdan

The control group studied the regular textbook with their own teacher. The experimental group was given the treatment described above plus the textbook. Both groups were pretested and post-tested before and after the study was conducted.

Data Collection Procedure

Designing the tests

There were eleven questions in the pretest and posttest used for statistical data analysis. These questions are listed as part of Appendix D. All students were pretested on the 11th of September 1986, and posttested again on the 15th of October 1986. In each question, students were asked to circle the correct answer and put their reasons for choosing these answers in the space under the question. The first question tested students' general knowledge about the function of light, soil and air in plants (Bishop et al., 1985). The second question (designed by the researcher) is an imitation of Van Helmont's 17th century experiment to test students' knowledge about the role of soil in plant growth. The third one tested students' knowledge about the relative percentage of carbon dioxide and oxygen production in plants and animals, a late 18th century discovery (Smith, et, al. 1985). The fourth question (designed by the researcher) tested students' knowledge about the importance of light in forming glucose. The fifth one (designed by the researcher) tested students' knowledge about the importance of minerals in plant growth. The sixth, seventh and eight questions addressed the function of respiration which was discovered in the second half of the 19th century (Bishop et al., 1985). The ninth question tested students' knowledge about the importance of the cyclical work of enzymes in maintaining life. The tenth question tested students' knowledge about connecting the work of enzymes to DNA to rationalize the differences between people's adaptation to environmental conditions. The eleventh item was a general question testing students' knowledge in all the issues that had been discussed. The ninth, tenth and eleventh questions were all designed by the researcher.

All of these questions were used in statistical data analysis; only seven were used for qualitative data analysis. The fourth item and the ninth, tenth, and eleventh items were excluded from qualitative data analysis. The reason is that the students did not give enough information during the lessons on the function of enzymes and its relation to the DNA. The fourth question was excluded because it did not give any specific information about the conceptual structure of students. When students answered the latter four questions in the pre and posttest, about the function of enzymes and their relation to DNA, they used general terms, circling the correct answer without being specific in their reasoning. Lacking any information from the dialogue to specify what they really understood, I chose not to include these items in the qualitative data analysis. To a degree, the same problem occurred with the other seven questions, but additional data, from students' dialogues during instruction and from their homework, enabled defining students' conceptual structure of the issues addressed in the earlier seven questions about photosynthesis and respiration.

This raises a question of why I used all the items in the statistical data analysis in the first place. There was no way for me to discover earlier those students who were inconsistent in their answers, so I took their answers as it was presented in the statistical analysis and evaluated their answers depending upon the criteria that I set. These criteria and the students' answers are presented in Appendix D. It was the qualitative data analysis that showed me that I could not take the students' answers for granted, without assessing them throughout the discussion and the homework. This is because the students were so fluent in using terms that sounded correct, but held different meanings for the students and the researcher.

All the test questions are presented in the appendix in two tables. The first table contains all the questions (Appendix D). The second contains those questions used in the qualitative data analysis (Appendix A).

Data collection in the class setting

Seven enriched lessons, based on historical discoveries of the biochemical activity of the cell, were used in the treatment. These were taught from the 11th of September until the 15th of October 1986. There were two lessons every week. Duration of lessons was forty-five minutes each. The first and second lessons concerned the function of photosynthesis. The third lesson was about the function of respiration. The fourth lesson was on the function of soil. Part of the fourth and the fifth lessons dealt with the metabolism of protein. Part of the fifth and sixth lessons were about the process of respiration. Part of the sixth and seventh lessons concerned the function of co-enzymes in the respiration process. The last part of the seventh lesson connected the work of DNA to the work of co-enzymes. An audio recorder was used to record the dialog between the teacher and the students throughout the seven lessons. Data from these audiotapes supplemented by data from homework and tests were analyzed to build the conceptual structure for each student in the experimental group.

The questions asked by the teacher, the biological phenomena the students were asked to explain, and the rationale for these questions, which match the questions scientists asked when trying to explain the phenomena in the history of science, are presented in Appendix C.

Data collection from students' homework

Seven questions were given to the students, one after each lesson. Each question tested the students' propositional knowledge about the issue under study in the lesson. Each question asked the students to explain the biological phenomena being studied. The first four questions were taken from Smith and Anderson's study (1986). The last three were from the textbook. All the questions are presented in Appendix B.

Scheduling and setting

The same questions were used in the pre and post-tests for both the experimental and control groups. Students were given forty-five minutes to answer the questions; many completed them in less time. The seven lessons were forty-five minutes long; two lessons per week. Each lesson was audio-recorded. After each lesson, the students were given a homework question to be returned with the next lesson. No homework or recording of dialogue was used to collect information in the control group. It was used as a control group in statistical analysis only.

Limitation on collecting data

There is missing data for students in the control group, for I had tested them only before and after instruction, asking questions that measured their ability to make correct predictions about the phenomena. I assumed the questions in the pretest and posttest would give me enough information about their conceptual structure. However, it turned out that many students were using general terms in explaining their answers. Here, I depended on the dialogue and the homework to assess what students really understood in the lessons about photosynthesis and respiration. I chose not to discuss the conceptual structure of students in those issues in which the students were not participating articulately in the dialogue regarding the function of enzymes and its relation to the function of DNA in qualifying data analysis.

Another limitation was the small sample size which limits the power of generalization. This was unavoidable, however, since the basic objective was to have detailed and accurate information from the students. It would not have been practical for one researcher to use a larger sample and still get rich and detailed information from every student.

The time that was arranged for instruction was another limitation. Although I used the period arranged by the regular teacher to teach the textbook material, I think that given the richness of information that was implied in the treatment and the method of inquiry, more time could have been used to assure that every student followed the logic of inquiry.

Data Analysis Procedure

Quantitative analysis

To assess the effect of the treatment, the analysis of covarience (ANCOVA) was used. This method increases statistical power and reduces bias (Glass and Hopkins, 1984). For example, if there were prior differences in achievement between the experimental and control groups, ANCOVA tries to control such prior differences by considering the prior achievement as a variable to be controlled statistically. The F ratio would then be calculated depending on the difference in achievement after the treatment. It would be favorable, when using this method, to assign students randomly to both sections, in case the presence of other confounding variables might be overlooked. When conducting the research, I depended on the fact that students, at the beginning of school year, were assigned to both sections on an equal basis. I designed the program for statistical analysis, using Spreadsheet (Applework program). The program was tested by introducing data in a proven example from Glass & Hopkins ((1984. p 496). This program gave the same results that were obtained in the example in the book.

Significant statistical differences between the pretest and posttest for the experimental group, were used to test the effectiveness of the treatment in reducing misconceptions the students have in explaining everyday life phenomena (functional knowledge). The criteria I depended on in evaluating students' answers for the statistical analysis, are presented in Appendix D. I entered all the students answers into a data base, assigning code and grade for each answer. The highest grade given was 5, which represents the answer that best agrees with the current scientific idea. The lowest grade is 0, which was assigned to answers most similar to early scientists' ideas (Aristotle) or for answers that did not show any base for what scientists believe in now. There were arbitrary grades (between 1-4), assigned on whether the idea had ever arisen in the periods of scientific discoveries (16th through 19th century) or because the answer had some scientific bases. The criteria for choosing the grades are represented in Appendix D. The data base program on Applework collected the total grades for every student. The grade was then transferred to the Spreadsheat in the same program for statistical data analysis.

Qualitative data analysis

Answering the first question of the dissertation. The purpose was to study if students tend to build coherent theories about photosynthesis, respiration and ecosystem in the same way it happened in the history of science.

To answer this question, the students' ideas about the source of plant growth, the way the food is metabolized, the type of material used in respiration, the function of respiration and its location, were used as categories to explore how students explain these issues. The answers were studied in the pretest, the lessons and the posttest to uncover all different types of naive theories. Tables and case studies were done to examine how students restructured their knowledge in each issue as a consequence of instruction.

Answering the second question of the dissertation. The purpose of the second question was to compare the group of students in the experimental group who succeeded in restructuring their theory and those who did not. The focus of comparison was on students' entry level knowledge, and the ways in which the treatment affected their thinking. The soul of the question was derived from the primary assumption that the students did not form theory spontaneously. Sociocultural factors described by Vygotsky, such as previous instruction, played an important role. To verify that, four dimensional comparisons were done regarding the effect of textbook conceptualization; what textbook conceptualization has to do with the development of this topic in the history of science; how the two together affect the entry level knowledge of students, and what all this has to do with the logical organization of instruction. Students were divided according to the nature of their naive theories on the issues mentioned above. Case studies were done in Chapter 5 to compare students who failed to restructure their theories and those who succeeded. The comparison focused on the students' entry level knowledge, the type of reasoning they used, and their methods of processing the information.

CHAPTER IV

RESULTS AND DISCUSSION

The previous chapter explains the methods used to collect and analyze the data. In this chapter, I will first present the statistical results. This analysis was originally done to assess the effectiveness of the treatment. In the sections following this statistical analysis, the results of the answers to the two questions asked in the dissertation will be presented.

Statistical Data Results

Primarily, I used the statistical analysis to assess the effectiveness of the treatment. The questions tested the students' ability to explain the phenomena of the natural world in a scientific way. This was the criterion I used to assess the success of the treatment. This criterion was derived from an understanding that students' naive ideas about the phenomena inhibit their understanding of the scientific concepts.

Students' scores in the statistical analysis were derived from the grades they received when answering the questions that measured their ability to relate what they understood from textbooks about the biochemical activity of the cell to everyday phenomena. For information about the grading procedure see the methodology and Appendix D.

Before discussing the statistical results, an explanation of the codes used in this table will be presented.

CONTR = control group.

EXPER = Experimental group.

PRE T = pretest.

POS T = posttest.

X SQ = X Square (pretest scores).

Y SQ = Y Square (posttest scores.

Tot = Total.

AVG = Average.

TOT con = total scores for the control group.

TOT exp = total scores for the experimental group.

AVG con = the scores average for the control group.

AVG exp = the scores average for the experimental group.

TXX = the total variance between the pretest scores (between the experimental and control group on the pretest).

TYY = The variance between the posttest scores (between the experimental group and the control group on the posttest).

TWX = The variance within the pretest groups.

TWY = The variance within the posttest groups.

RT = the correlation coefficient between groups.

RW = The correlation coefficient within groups.

EXPLIN BY COV = Explained by covarience.

UNEXP BY COV = Unexplained by covarience.

ADJ BETW = Adjustment between scores of pretest and posttest scores.

ADJ WITH = Adjustment within scores of pretest and posttest scores.

Table 2

Statistical Results and Analysis

		PRE T	X SQ	POS T	Y SQ	X.Y
CONTR	AMAL	20.0	400.0	25.0	625.0	500.0
	AMENA	34.0	1156.0	36.0	1296.0	1224.0
	EMAN	27.0	729.0	31.0	961.0	837.0
	FADWA	30.0	900.0	27.0	729.0	810.0
	HANAN	30.0	900.0	27.0	729.0	810.0
	KAREYMA	25.0	625.0	31.0	961.0	775.0
	ROWLA	17.0	289.0	23.0	529.0	391.0
	SAMEYRA	35.0	1225.0	31.0	961.0	1085.0
	TAGHREYD	33.0	1089.0	38.0	1444.0	1254.0
	WEJDAN	21.0	441.0	22.0	484.0	462.0
EXPER	ABEAR	16.0	256.0	41.0	1681.0	656.0
	ASMA	22.0	484.0	42.0	1764.0	924.0
	BASEMA	21.0	441.0	39.0	1521.0	819.0
	FATEMA	22.0	484.0	39.0	1521.0	858.0
	GHAYDA	31.0	961.0	45.0	2025.0	1395.0
	KHOLOWED	28.0	784.0	48.0	2304.0	1344.0
	OHOWED	31.0	961.0	43.0	1849.0	1333.0
	SALAM	32.0	1024.0	50.0	2500.0	1600.0
	SAWSAN	31.0	961.0	42.0	1764.0	1302.0
	SUMAYYA	21.0	441.0	40.0	1600.0	840.0
	TOT	527.0	14551.0	720.0	27248.0	19219.0
	AVG	26.4		36.0		
	TOT con	272.0		291.0	8719.0	8148.0
	TOT exp	255.0		429.0	18529.0	11071.0
	AVG con	27.2		29.1		
	AVG exp	25.5		42.9		

TXX	664.5	TWX	650.1
TYY	1328.0	TWY	578.0
TX.Y	247.0	TWX.Y	484.5
RT	.3	RW	.8

Table 3

ANCOVA Table

SOURCE	SS	DF	MS	F
EXP BY CO	$R^2t*T.Y$			
	91.8	1.0	91.8	4.8
UNEXP BY CO	$T.Y(1-R^2t)$	18.0		
	1236.2			
ADJ BETW	931.9	1.0	931.9	48.9
ADJ WITH	$TW.Y(1-R^2w)$	17.0		
	323.8			
TOTAL	1328.0	19.0		

F=15.71,17,.001. 48.9> 15.7.

<u>Discussion</u>

The result is statistically significant. It appears that in the posttest the experimental group was more successful than the control group in using scientific concepts to explain everyday phenomena. Initially there were no significant differences between the experimental and control groups on the pretest, 4.8 < 15.7, implying that the differences were caused by the treatment.

In the pretest, there were many students in both groups who predicted that the weight of plant come primarily from soil and water. There were also many students in both groups who did not know that the function of respiration is to provide energy, and that it happens in every cell (they mostly singled out the lung and the skin). Also, they did not know the exact role of DNA, or its relation to the function of enzymes. For example, one student in the control group, during the pretest, mentioned the reason for the inherited diseases in some families is that germs transfer through genetic codes. However, she changed this answer in the posttest, saying that germs only come from the outside environment.

Comparing students' answers in the posttest reveals that the experimental group gave more accurate answers; mentioning that plants grow primarily because of photosynthesis (the second question); that respiration happens in every cell, not just the lung (the seventh question); and that the function of respiration is to give energy (the eighth question); that respiration is a chemical process that could happen outside the body if the necessary enzymes were available (ninth question); that environmental and genetic factors control the degree of adaptation. The treatment allows students to connect what they studied in the textbook with what they observed to explain the events in a scientific way. The scale shows that three students in the control group received lower grades on the posttest than the pretest. The students in the experimental group had the advantage of the treatment, which emphasized the role of the soil; students became aware that minerals, such as nitrate and phosphate, are used by the plant to build protein, nucleotides, etc. No student in the control group posttest predicted the importance of soil, although many of them did so in the pretest. The reason is that the students study the textbook section on Van Helmont's experiment, in which he incorrectly concluded that the weight of the plant comes just from water. The textbook discusses the role of photosynthesis in plant growth without mentioning the role of soil. This was discussed in another unit of the textbook. Affected by that, no student in the control group mentioned, in the posttest, any role for the soil in plant growth.

The qualitative data analysis, in the next section, shows that the criteria used to measure students' understanding for this statistical data analysis were not sufficient. That is because many students were able to relate the scientific concept, on the surface, to explain everyday biological phenomena, while continuing to hold naive ideas in their propositional knowledge. They did not have a deep understanding of many abstract concepts such as conservation of matter in photosynthesis and respiration, and control of enzymes by DNA. These concepts were discovered only through qualitative data analysis. Students know that a plant receives just a small percentage of its weight from soil, since it makes its food through photosynthesis. They know that environmental and genetic factors are both important for growth. However, if asked to explain specifically, the function of carbon dioxide and the DNA, they would show a poor integration of knowledge of how carbon dioxide consumed through photosynthesis formed the organic compounds to be released through respiration; they did not know how DNA controls the work of enzymes, nor would they be able to explain the differences in metabolism and feeding between species as a consequence of the controlling the work of enzymes by the DNA. Students gave general articulate answers on these issues.

Qualitative Data Results

Introduction

To illustrate the conceptual structure of students in the experimental group, I developed two tables (Table 4 and 5 below). Table 4 was developed by examining students' answers to the seven questions about the function of photosynthesis and respiration in the pretest (see appendix A). Students' answers in the first lesson on photosynthesis, the second lesson on the source of material that gave energy and the third lesson on respiration were also analyzed. The concept that students had a naive theory about is indicated in the longitudinal category. There were four horizontal groups in the Tables. The students were assigned to a given group according to their similar their naive ideas on the concepts under study. These tables illustrate the main findings that the study reveals: students found to have one misconception in one concept are also found to be the same students who have other related misconceptions in other concepts, and their restructuring of theories are the same. Table 5 is developed the same way, using the same horizontal and longitudinal categories. The difference this time is that the students' answers were followed in the posttest, their homework, (the homework questions are in Appendix B), their reasoning on the fourth lesson about photosynthesis, and the fifth and sixth lessons on respiration. Table 4 illustrates students' entry level knowledge, and Table 5 illustrates students' theories after instruction.

Table 4: Students' Entry Level Knowledge

	Issue	Vitalism groups: group 1	Vitalism groups: group 2	Conserving of matter groups: group3	Conserving of matter groups: group 4
prop knowledg	Fate of carbon dioxide	respiration in plant	respiration in plant	enter photo reaction	enter photo reaction
	Material used to get energy	water	light	organic material	organic material
	product of respiration	water vapour	energy	carbon dioxide & water	carbon dioxide & water
Func know ledg	Source of material for growth	photo means nothing to return to fertalize the soil	photosynthsis means light	soil	prior condense matterial formed in photosynth
	organisms that respire	all for energy	all for energy	all for energy	some
cut& try infr	Location of respiration	lung & skin	lung	lung & skin	lung & skin

Table 5 Students' Conceptions after Instruction

	Issue	Vitalism groups: group 1	Vitalism groups: group 2	Conserving of matter groups: group3	Conserving of matter groups: group 4
prop knowledg	Fate of carbon dioxide	respiration in plant	respiration in plant	enter photo reaction	enter photo reaction
	Material used to get energy	light	chlorophyl	organic material	organic material
	product of respiration	energy (particles)	energy (particles)	carbon dioxide & water	carbon dioxide & water
funct know-ledge	Source of material for growth	photo means nothing to return to fertalize the soil	photosynthsis means light	photosynthsis means reaction carbon dioxide with water	photo means reaction carbon dioxide with water
	organisms that respire	all for energy	all for energy	all for energy	all for energy
cut& try biolg infor	location of respiration	cell	cell	cell	cell

<u>Illustrating the categories in the tables</u>

The student groups were divided into two main horizontal categories; 1) the vitalistic group, whose answers revealed they do not believe that human bodies are formed from the same elements found outside, and 2) the conserving of matter group, whose answers revealed that they tend to believe this is so.

The main longitudinal categories were:

1) Propositional knowledge, knowledge that deals with abstract scientific concepts. The sub-categories include : a) fate of carbon dioxide, b) source of material used to get energy, and c) product of respiration.

2) Functional knowledge, knowledge that deals with explaining biological phenomena. The sub-categories included; a) source of material for growth, and b) organisms that respire.

3) Knowledge that was discovered through cut and try, (i.e., open the stomach and see what is happening without having a predetermined theory). The kind of knowledge discovered this way was the location of respiration.

Illustrating the sub categories: The phrases described students' ideas is a little abstract for this limited space in Table 4 and 5 to give sufficient description. The following illustration may help the reader: Every block has a longitudinal and a horizontal dimension. For example, the first category, at the upper left end in Table 4, is "respirations in plants". Looking at the horizontal dimension, one finds the category "Group 1", and at the longitudinal dimension one finds "fate of carbon dioxide". This means that students in group 1 tend to believe that carbon dioxide is used for respiration in plants. Whenever the word "photo" appeared, it means photosynthesis.

Answers to the first question of the dissertation

Readers will recall that the first research question is as follows:

1- To what extent do the connections made by students in their partial theories about scientific concepts that underlie the biochemical activity of the cell follow the same coherent conceptualizations found in the history of science?

The study reveals that students tend to have coherent misconceptions on many of the concepts that underlie the topic. These coherent misconceptions are similar to what was observed in the history of science. Students with one type of misconception on photosynthesis are the same who had related misconceptions on respiration and ecosystem.

Students in the first group believed that an organism's tissue grows from organic material. This seemed to be a scientific idea. However Table 4 shows the problem is they did not relate organic compounds to photosynthesis in a scientific way. They thought that organic compounds form nothing but water through photosynthesis. This is what they only understood from the statement; "plant makes its food by itself." This group of students, however, was found to share the same misconception that the material burned through the respiration process is water. In the posttest (as shown in Table 5) they all concluded that the body of the plant comes from light. They also think of energy as particles and that during respiration organic material is released only in the form of energy only.

Students in group 2 had the misconception that the weight of a plant comes from light (Table 4); the study also indicated they were the same students who thought organic material was only released in the form of energy. In the posttest, when convinced that light is almost weightless (see case study 1, Chapter 5), those students changed their thinking to say that the body of the plant came from the division of chlorophyl cells (Table 5). It should be explained that there is nothing in the biology textbook called chlorophyl cells; although, there is a chlorophyl diet, a chemical compound that absorbs the light at a certain wave length. Chlorophyl is found in the plastids of plant cells, mostly in the leaves.

In contrast to the earlier groups, the third and fourth groups of students knew from the beginning that, through photosynthesis, carbon dioxide combines with water to form glucose (at the final stage). They also knew that glucose decomposes through respiration, into carbon dioxide and water (see Table 4). In the pretest, however, they did not demonstrate acquiring the scientific idea about the function of photosynthesis. Students in group 3 thought photosynthesis only provides energy, while group 4 stated that photosynthesis only builds plant tissue. All students in the third and fourth group succeeded by the end, in using their propositional knowledge to explain everyday phenomena in a scientific way (correct functional knowledge) (see Table 5).

This analysis demonstrates it was a mistake to depend on questions in the tests that measure the students' acquisition of correct functional knowledge (ability to relate their scientific information to everyday phenomena), as a criterion for the success of the treatment (in the statistical data analysis).

Driver and Erickson (1983) discussed the problems that arise in collecting data about students' conceptual structure, where metaphoric language is used to define the issue:

> In probing students' knowledge structure, inferences are made based on available data about the knowledge structure. Students responses may differ significantly depending on whether they are investigated

> using a technique which is conceptually framed, or one based on an actual event or phenomena, the former is called propositional knowledge, and the latter is called knowledge in action ... Although an important feature of an expert scientist's thinking is the ability to move between the theoretical and sensory domain and to bring propositional knowledge to bear in practical situations, these two manifestations of individual conceptual framework may not necessarily be related. Indeed this may be the case for much of school science knowledge (p. 43, 46).

Driver and Erickson's argument is obvious in the differences found between students' conceptual structure in this dissertation. Students in the first group gave correct answers from the beginning (in the pretest) when the situation was related to their knowledgeable use of reasoning about the biological phenomena (as shown by the functional information of students in Table 4 and Table 5). Students in the first and second groups were consistent in relating their knowledge of photosynthesis and respiration to everyday biological phenomena in a scientific way. They knew photosynthesis is used to build plant bodies and to condense the energy that organisms later release through respiration. For example, when asking how much soil is lost as the plant grows, all but one of them circled the option that soil loses less that 1% of its weight. When asked which organisms engage in respiration, all students in those groups circled "all the living organisms," including bacteria, and plants. They also said during lessons that respiration was used to provide energy (Case Studies 1, 2, 3).

Their answers on the homework and discussions illustrate that these students lack the basic understanding of the principles in physics and chemistry that allows them to truly understand these procedures- that is, they had misconceptions in propositional knowledge. As Table 4 shows, the first group thought that organic material forms from nothing but water during photosynthesis, and then plants return to fertilize the soil by this organic material (planting crops in soil would fertilize the soil). Further, since the question referred to grain, it is reasonable to assume that students did not mistake the action of legumes in enriching soil.

Organic compounds were thought to be decomposed into energy and water vapour by students in the first group; or into just energy by students in the second group (Case Study 2). Neither group thought that breathing (absorbing oxygen and releasing carbon dioxide) was at all related to the process of converting food into energy (Case Study 3).

The analysis showed students in the third and fourth group in Table 4 had a good propositional knowledge before the treatment. They knew the exact meanings of photosynthesis and respiration. They knew that in photosynthesis, carbon dioxide combines with water to form glucose (Case Study 1), and that the products of respiration (carbon dioxide and water vapour) are released as a result of oxidizing glucose in the respiration process (Case Study 2). This propositional knowledge is similar, in a certain degree, to the propositional knowledge of scientists in the third paradigm (see the literature review). Still, those students had some serious misconceptions in their functional knowledge. Unlike the first and second group, the third group believed that the weight of plants comes from soil, while photosynthesis is then just a method to condense the energy necessary for respiration (Case Study 1, and Table 4). The fourth group, although knowing that the body of a plant is formed through photosynthesis, still, believe that respiration is only a breathing process, not for providing energy (Case Study 2, Table 4). The treatment allowed them to integrate their propositional knowledge about photosynthesis and respiration to a comprehensive view about their functions in the body (Case Study 4, 5, 6, Table 5).

Table 5 shows that the first and second groups of students still held naive ideas about what photosynthesis really is, even after instruction. The data came mainly from homework, dialogues, and some from posttest answers. The organic material that formed through photosynthesis meant energy to students in the first group, and chlorophyl to students in the second group. They also thought of respiration in terms of energy only.

Unlike the first and second group of students, Table 4 illustrates that the third and fourth groups primarily came with good propositional knowledge, knowing that carbon dioxide combines with water to form glucose and that glucose in turn converts into carbon dioxide and water during respiration. Through instruction, those students succeeded in combining their propositional knowledge with a good understanding about the function of photosynthesis. They came to realize that photosynthesis produces the organic material used for providing energy and building the interchangeable parts of the body.

By the end of the study, all the students knew that plants absorb less than 1% of their weight from the soil and that all organisms respire to produce energy that happens in every cell.

In summary, analysis of the students' answers show that some students have coherent but idiosyncratic ideas about all the concepts under study. The same group of students, Group 1, who believed that plant bodies form through photosynthesis from nothing, are the same who think water is the material used in respiration to produce the energy in which water vapour is released through the process. They are also the same group who restructured their ideas (Table 5) to say that light is the material the body is formed from, and that this material is released in the form of energy "particles". The same group of students, Group 2, who thought (see Table 4) the plant's body is formed from light are the same who believed it was released in the form of energy "particles." They are also the same who restructured their idea (see Table 5) to say that organic material is formed from "the division of chlorophyl cells".

Groups 3 and 4, who know that carbon dioxide combines with water to form glucose are the same who know that organic material is decomposed in the form of carbon dioxide and water. Those groups initially came to the study without a full understanding of the function of photosynthesis; the third group thought it was just for condensing energy, while the fourth thought that it was just for constructing building blocks. As is shown in Table 5, both groups succeeded in having comprehensible ideas about the function of photosynthesis.

The analysis also reveals that none of the students were initially aware that respiration happens in every cell (Table 4 and Case Study 3). This was an advanced discovery in the history of science which occurred in the second half of the 19th century. They succeeded in answering this question after instruction (Table 5 and Case Study 3).

The results emphasize what Driver and Erickson suggested, that relating scientific concepts to everyday phenomena does not guarantee the acquisition of propositional knowledge. A clear example of this is the first and second groups' responses in Tables 4 and 5). The dissertation results reveal that the acquisition of propositional knowledge in the students under study does not guarantee their ability to relate this knowledge to everyday situations. Groups 3 and 4 provide examples of this as shown in Table 4.

Students' conscious inference to rationalize their theory was not identified as a missing element in students who fail to restructure their knowledge. However, correct integration for information obtained by students inferences was missing in the first and second groups. The information was integrated in the wrong way. Every misconception appears to be related to another misconception in a related topic. Those who believe light is the source of weight, also believe that losing weight would result from release of energy. Carbon dioxide, considered here to be used in human and plant breathing, has nothing to do with burning material. Moreover, they did not know that carbon dioxide enters to form plant material.

However, Piagetians criterion for reaching the ultimate stage of scientific reasoning require conscious consideration for all the partial theories that formed through conscious inference. This criterion is viewed as still missing in students who failed to restructure their theory.

When students in the first and second groups were asked to make inferences on specific facts, they were able to do so (Case Study 6). But when they were asked to provide reasoning for the function of DNA, to define reasons for variance in feeding habits and adaptation from one species to another, which needs a systematic integration of correct information on the biochemical activity of the cell, they often gave general, irrelevant answers. Only one of the students in the fourth group (Sawsan) was able to give specific, explicit, and correct answers (Case Study 6).

The previous research and the results revealed through answering the first question of the dissertation: Many of the misconceptions identified in this dissertation had been identified in many previous studies. The presence of functional knowledge that differs from the scientific point of view in students was identified by Anderson and Smith (1986) on ecosystem (e.g.,. weight of plants comes from soil or water). Also, Wandersee (1983) found that students believe that the weight of plants comes from soil and water and plants add something to the soil. Further, Bishop et al. (1985) studying photosynthesis and respiration, showed that prospective elementary teachers equated respiration with breathing.

Students' misconceptions in their propositional knowledge was mainly identified by Treagust and Haslam (1986), who discovered that secondary school students believe that carbon dioxide is used in plant breathing, and that plant growth comes from chlorophyll. Smith and Anderson (1986) identified students who believe that food converts into energy. Wandersee (1983) identified students who believed that the material from which organisms grow is energy. Wandersee shows that this tendency appears more with students in higher grades.

The unique thing about the findings in this dissertation is that it shows that those misconceptions tend to be coherent. The same student was examined throughout a month-long instructional period, to see how the concepts related to each other. Moreover by discussing related concepts during instruction, and by using questions which elicited both propositional knowledge and functional knowledge, it became possible to discover allowed discovery of the interconnection among concepts held by each of the students as well as the presence or absence of either type of knowledge in these students.

Another related finding, besides the tendency of students to have coherent conceptions in all the related issues that underlie the topic of the biochemical activity of the cell, is the ability of students to consciously explain and rationalize their ideas (see Case Studies' dialogues).

However, the study shows that many of those students were still at the primary stage of forming their theory. Some of them still had erroneous ideas in their propositional knowledge. This type of knowledge, which tends to be abstract, needs a basic understanding of the fundamental principles in chemistry and physics. This means that the students in the first and second groups did not reach the desired end stage of mentally reflecting on abstract ideas that characterize physics and chemistry concepts.

Analysis of answers by students in the third and fourth groups shows that they demonstrated abstract reflection on their own theory. For example, in Chapter 5, see the Case Study 3 of Salam's dialog about the needs of oxygen, and contrast that with what Kholowed understood from Salam's question. Another example can be found in Sawsan's dialogue in Case Study 6 which is in contrast with the dialogue of Basema and Abear.

According to Piaget, having the ability to reflect abstractly on one's own thinking should accompany the ability to use this knowledge to explain everyday life phenomena in a scientific way (Carey, 1982, Brown et al., 1983). This raises interesting questions of why those students who initially came to the study with the ability to reflect abstractly on their own thinking (having a good coherent theory regarding their propositional knowledge in chemistry and physics --students in the third and fourth groups), held a naive idea in their functional knowledge before instruction? And why those who still had not reached the stage of reflecting abstractly on their thinking, were able to generalize their knowledge and explain scientifically everyday biological phenomena at least in a superficial way? Is student theory spontaneously formed, as Piaget would claim, or do sociocultural factors, including the curriculum and instruction in school, play a big role in their formation? Why were students in the fourth group, although identified as having a good ability to integrate information abstractly to form a unified theory, not able to do that without instruction? And why were students in the first and second groups able to use their knowledge in a scientific way, although identified as being unable to systematically integrate the partial theories they formed through their own inference? These questions could be partially explored when answering the second question of the study.

Answers to the second question of the dissertation

The question that was investigated was how entry level knowledge, textbook information, and a treatment based on the logical-historical development of scientific ideas influences the development of students' theories. These factors represent the internalization of sociocultural knowledge by the learners when forming their scientific theories.

Entry level knowledge: The propositional knowledge of students in the first and second groups was similar to that of the scientists in the second paradigm who developed this topic in the history of science. Like the scientists in the past, those students believed that carbon dioxide is used by plants for breathing, and that heat energy is made of particles that can form the weight of the body.

Those students in the first and second groups were not able to explain their observations following the physical chemical laws. In the tradition of vitalism, they believed that living organisms are not subject to the same laws that apply in physics and chemistry. The first group of students believed that planting crops in the field would add something vital to the soil (Case Studies 1 and 4). They also believed that water decomposes to provide energy. After instruction, they began to consider that organic materials were the source that provides energy, although they still had the naive idea that organic compounds contain heat particles (Case Studies 3 and 5).

The second group demonstrated vitalistic thinking of another sort. When this group was convinced in class that light is without a mass, they began to consider the division of "chlorophyl cells" as the reason for plant weight (Case Study 1). "Chlorophyl cells", in this context were not mentioned in any biological textbook. Chlorophyl is found in the plastids; its function is to absorb the light. The energy from the light is stored in the ATP, and ultimately in the organic bonds that form as carbon dioxide combined with water to form organic compounds.

The energy stored by chlorophyl is used first to separate oxygen from hydrogen in the water molecule. Oxygen is released, while hydrogen forms a glucose molecule with carbon dioxide. This means that the energy used to separate water molecules is stored in organic molecules. The plastids that contain the chlorophyl are found in some plant cells (mainly leaves). Students did not understand that the function of chlorophyl is to absorb the light (as defined in the textbook). They thought that chlorophyl is a kind of cell which is responsible for plant growth through its division.

This is also vitalistic thinking, for the students thought that "chlorophyl cells" in plant would produce material through its division, independent from outside resources. This is the same conceptualization observed in the history of science. Biologists who were working independently from natural scientists believed that the growth happened from cell division, independent from the inorganic material that is absorbed from outside (Chapter 2, Third Paradigm).

Of all the students who initially thought that light gave weight to the body, only one succeeded in making a shift to the contemporary scientific theory. However, this girl (Ohowed) did not demonstrate vitalistic thinking. She had a conceptual structure very similar to Lavoisier in the third paradigm. Although Lavoisier and his associates knew that carbon dioxide and water entered into the process of photosynthesis to be released by respiration, they still thought of energy as particles. Explaining to Ohowed that light is almost weightless enabled her to have a good scientific structure. This was unsuccessful however, with students who demonstrated vitalistic thinking. They still thought of carbon dioxide for breathing, and even if they believed that carbon dioxide entered to stay, and not merely flowing in and out, maintaining vitalistic thinking prevented them from forming a good scientific point of view in the same way as Ohowed. They still thought plants grow idependently from outside resources as demonstrated in Asma's dialogue in Case Study 1.

The analysis showed that this propositional knowledge, which is common to that of the scientists in the second paradigm, changed only slightly through instruction for the first and second groups of students. The first group concluded that light and organic material are the source of plants' weight. The second group concluded that chlorophyl, instead of light, was the source of weight (Case Study 5, and Table 5).

Textbook information: As discussed earlier in Chapter 3 (methodology), the conventional way of isolating conceptualization in different fields of biology (Chapter 2, Fourth Paradigm) is followed in the textbook. The conceptualization followed the 19th century's mechanistic, functional approach in understanding the biochemical activity of the cell. Plants were considered as manufacturers, and animals as consumers. The word "food" was used to mean "energy," stored between hydrocarbon bonds, since at that time scientists did not know the source of energy that was stored in organic bonds and released through oxidation. Scientists thought plants had a secret, vital force to condense this energy. The textbook adds some clarification by illustrating that energy comes, in the first place, from the sun. The textbook tried to influence the students' conceptual structure regarding the function of food to produce energy by connecting the mechanism of photosynthesis with respiration.

Although the question currently asked by scientists deals with explaining the differences observed between a variety of different species' feeding and adaptation habits, this was still not pointed out here. It could be that the textbook considered it an evolutionary problem. The textbook presented the propositional facts about the biochemical activity of the cell discovered during the 1960s. However, the conceptualization and classification of information followed the old 19th century conceptualization in biology, long before new facts about the structure and function of coenzymes and DNA was discovered.

The structure of organic material was given in a separate chapter. Historical experiments were not used to enhance students' understanding using their own inferences; the only thing presented was the scientists' "wrong" historical conclusions for the experiments which later were modified.

The affect this had on the students' conceptualization is discussed in the following section:

The first and second groups of students employed the same vitalistic thinking from the second paradigm: plants have a secret force to build the body from water, while air is used for breathing. For those students, textbook discussion about the function of respiration and photosynthesis supported their vitalistic thinking. As a result, students who entered with a vitalistic viewpoint could understand the textbook's conceptualization of the function of photosynthesis and respiration since it was congruent with their vitalistic thinking. In

Case Study 2, Kholowed stated that the original source of energy released in respiration is solar energy, which is stored in organic compounds through photosynthesis. At the same time (in Case Study 3), it was evident that Kholowed thought organic compounds produced only energy, while breathing (i.e., taking in oxygen and releasing carbon dioxide) had nothing to do with the process.

When it came to propositional knowledge of the textbook on how carbon dioxide combined with water to form glucose (Kelvin cycle) and how glucose is oxidized (Kreb cycle), it was evident these facts were ignored or modified by those students, since they did not match their vitalistic thinking. When the textbook said that food (meaning energy) is stored inside organic compounds to be released by respiration, the students interpreted this to mean that organic compounds are just energy. Moreover, students thought that the material our bodies are built of is not the same elements found outside.

When the researcher told Kholowed that light is weightless, she stated in return that the division of chlorophyl cells was a source of weight. This is a typical case of modifying information that contradicts vitalistic thinking. Although those students employed vitalistic thinking about the conservation of matter, they understood well the conservation of energy, since earlier discussion shows the textbook stressed this point to make it comprehensible (Case Studies 2 and 3).

I would argue here, that initially this vitalistic thinking was not developed spontaneously, but from previous readings and instruction. Students were in the beginning stage of being consciously aware of how things work. They were trying to make sense of scientific information and explain their world according to it. However, they had to reach the final stage to see that this kind of understanding was inconsistent with basic "abstract" principles acquired in physics and chemistry. The content the students learned from the textbook was not necessarily scientific because of its use of analogies and metaphor. While some analogies and metaphors are helpful, students sometimes adopt the analogy or metaphor per se, which confused their understanding of scientific theory.

Students who maintained conservation of matter in their conceptual structure (the third and fourth groups), found it difficult to reconcile that concept with the textbook's conceptualization about the function of photosynthesis and respiration. These students had two options, either acquire vitalistic thinking regarding conservation of matter, or ignore some conceptualizations in the textbook, since they did not match their thinking.

In the textbook's presentation of Van Helmont's conclusion, "the body of plants comes from water," the textbook does not make it clear to students that this conclusion had been modified. Salam, in the third group, even though she well understood how organic material burns through respiration, ignored the findings of Van Helmont's experiments, maintaining her old ideas that in addition to water, 30% of plant's weight is contributed by the soil. If Salam accepted the findings of Van Helmont's experiment, she would have to ignore her understanding about the conserving of matter, and believe that water has the ability to form organic compounds.

The fourth group well understood that water combines with carbon dioxide to form the glucose used in building the body's tissue. However, if those students relied on the textbook to explain the other function of food, they would be in a dilemma. The textbook's functional information implied that plants have the ability to form tissue just from water, and the word "food" means the energy stored in organic bonds. It is my inference that those students chose to ignore these conceptualizations since it could not be consolidated with their own understanding about the conserving of matter. This means that students, who had reached a stage of scientific reasoning, were able to see the inconsistency between the information found in the historical experiment and the contemporary understanding of the basic principles of chemistry and physics. They were not able to stabilize this kind of functional knowledge as indicated by Salam's dialogue in the third group (Case Studies 2 and 3) which shows that she had a good understanding about the basic principles of physics and chemistry. However, she hardly attempted to see how this understanding would be compatible to what she saw in everyday life phenomena. Following Vygotsky's reasoning, acquiring and stabilizing revolutionary scientific concepts is a sociocultural process. Students could not assimilate, on their own, what was implied as propositional knowledge in the textbook, and relate that to everyday biological phenomena. There should be consistent resources from which they could internalize this reasoning, an element still not available to them before instruction.

<u>The treatment</u>: The treatment took into consideration the logical, systematic way of understanding the function of respiration and

photosynthesis. It was successful with the third and fourth groups of students, but not the first and second ones.

The reasons behind the different results with different groups of students, is that the treatment was designed to follow the logical restructuring of theory. It did not take into consideration erroneous conclusions generated from different metaphysical beliefs of students, nor did it stress teaching fundamental principles of chemistry and physics regarding the nature of light, energy and organic material. Vitalistic thinking was not discussed in class. The treatment followed the logical, accepted branch of developing the theory, not the ones which are no longer accepted.

The misconceptions that underlie vitalistic thinking and a lack of good understanding of the basic principles of chemistry and physics, became evident on occasion as when Asma (first group) thought plants could grow from nothing (Case Study 1). As the instructor in the class, I found it difficult, to analyze what was behind such illogical answers. Only a systematic follow up of the answers with the same students over time, allowed discovering that vitalistic thinking and a misunderstanding of the basic principles of physics and chemistry were the reasons behind some students' reasoning on the topic of the biochemical activity of the cell.

Some students consistently revealed reasoning that appeared illogical through their answers in the class. The teacher responded to these naive ideas with short, correct facts, such as "plants should take raw material from outside to be synthesized." This proved to be useless (Case Studies 1, 2, 3, 4). Those students, in fact, needed a structural change in their understanding of the basic principles of chemistry and physics, to know that physical and chemical laws which work outside the body are the same that work inside.

Since those students entered the seven lesson sequence with an accurate surface level knowledge about the functions of respiration and photosynthesis, they were occasionally able to mislead the instructor about what they really understood from the lesson. Discussion in Chapter 2, Third Paradigm, shows that a full understanding about the nature of heat was a prerequisite to understanding the mechanisms of photosynthesis and respiration in the history of science (Lanham, 1969). The study here shows that those students had similar misconceptions that heat and energy were just other types of materials. This also proves that separate, isolated facts in biology class were not sufficient in treating this kind of misconception about the nature of matter.

Previous studies and the findings of the research

According to the findings in this dissertation, students' naive concepts which are similar to the sophisticated concepts in the history of science were not developed spontaneously, but were derived from previous textbook readings, from people speaking (e.g., diets means fewer calories). Once those students acquired these misconceptions, they are hard to rectify through instruction, since these ideas would look scientific for them. Students could often explain the metaphoric language of the textbook in a way that matched their vitalistic thinking. This use of analogies makes it harder for students to get scientific ideas from the textbook. Driver and Erickson (1983) pointed this out as follows:

> Curriculum writers have often responded to the problem of presenting students with new and abstract bodies of content by making liberal use of analogies and models which they assume to be more familiar to the student (p. 49).

The data here shows that the liberal uses of analogies actually does not illustrate the concepts better. Instead, analogies often are subject to multiple interpretations. Students can interpret them as supporting their naive concepts, while teachers interpret them as supporting advanced concepts. Thus, the two can use the same analogy with quite different meaning. The reason for such uses is that curriculum writers were still affected by the historical statements, postulated by early scientists, in which these terms are used as facts, not analogies. Textbook authors mixed paradigms which causes confusion for students. An example is treatment of Lavoisier's invention of the term "calorie" in which he believed that heat was a fluid. The same postulated definition of "calorie" is still used in the textbook now. However, the curriculum writers expect students to know on their own, that those statements are just analogies.

Previous research on this topic emphasized the characteristics of the learner and his entry level knowledge as a reason for unsuccessful learning. Anderson and Smith explained that students' functional concepts were identified as barriers to understanding scientific concepts; however, this was done on students at younger ages. These naive ideas were the primary type, in which the functional knowledge of students contradict what people could feasibly test (e.g., soil as the source of food). Wandersee (1983) and Treagust and Haslam (1986) examined students at various developmental learning stages. None of these studies examined how sociocultural factors would work to stabilize students' naive theories.

This dissertation studies students at a higher stage, who became aware of their own theory and restructured it according to what made sense to them in the textbook. They used empirical findings that make sense to them (see Kholowed's argument in the third case study, and Basema's in the Fourth). These ideas were stabilized according to correct functional knowledge acquired from the textbook. They were able to relate everyday biological phenomena to scientific concepts and restructured their early spontaneous naive theories according to these scientific concepts. Still, the findings of this research show that this kind of understanding does not guarantee that students would obtain a good propositional knowledge, which is a point stressed on by Driver and Erickson (1983).

The treatment was effective only in the third and fourth groups of students who had notions about conservation of matter and found the rationale for the treatment matched their thinking. My inference is that those students used abstract thinking to test their ideas. An example of that is Sawsan in Case Study 6 successfully following up on instruction about the role of DNA (which needs a systematic connection of much information). Those students succeeded in integrating their information about the functions of respiration and photosynthesis in the way the researcher intended.

This research suggests that reaching formal operational thinking (e.g., being able to mentally test ideas and reflect upon them) did not guarantee that students would be able to generalize their information on their own, especially with a revolutionary type of science. (Carey, 1984, cited that many students at John's Hopkins University were not able to do that). Moreover, this dissertation shows that the students in the third and fourth groups were not able to do that if they had to depend on conventional curriculum, but there was a great improvement as a consequence of the seven lesson treatment. My inference is that, if the kind of functional knowledge that students at this stage are asked to acquire is not consistent with what students understand from different sources, such as the basic principles they have learned in physics and chemistry, it would be difficult for students to understand the integrated conceptual network of scientific explanation required in a topic such as the biochemical activity of the cell. Moreover, understanding of contemporary theories is confounded by textbooks that mix today's paradigms with prior ones without showing the reasoning that underlies their evolution.

The discussion here also emphasized the importance of other factors such as instruction and inference. The study shows that students who fail to restructure their theory had trouble considering many variables simultaneously. Still, I think that without consistent presenting, even the most capable students, would have trouble integrating scientific concepts on their own. The reason is that students who think reflectively would discover the inconsistency of the information they were asked to integrate, which adds to the difficulty for them.

Good instruction and a good sense of inference, alone are not enough without curriculum reform that adopts new paradigms in science. Textbook writers must be certain that the content included is logically consistent, and addressed to a consistent paradigm. Historical data can be used to strengthen understanding of how contemporary theory evolved, especially since the difficult conceptual problems confronted by scientists as they developed scientific theory may parallel the difficulties students have in learning it. The curriculum should also be guided by the philosophy of science in presenting scientific information. It is important to make it clear to the students that scientists' conclusions, in the history of science, were derived from their initial premises which were not sufficient to lead them to the most acceptable scientific theory. Teaching science should take into consideration students' entry level knowledge in other science fields, such as chemistry and physics, before presenting information they are expected to fully understand. The primary questions to be discussed would systematically follow the ones observed in the history of science as integrated of both the biology and physical chemistry information (see Chapter 2, the second, the third and the fourth paradigms)..

CHAPTER V

DISCUSSION OF THE CASE STUDIES

Introduction

Case studies have been developed pertaining to each category in Table 4 and Table 5. Case studies that illustrate students' entry level knowledge, as summarized in Table 4, will be presented first, followed by the case studies that illustrate students' understanding after instruction, as summarized in Table 5.

Each case study includes questions asked by the teacher and the way students in the various groups responded. The questions asked during instruction systematically follow questions scientists asked about the phenomena, in an attempt to lead students to make their own scientific reasoning. Those questions are presented with the rationale in Appendix C.

The conceptual structure for all students categorized in four groups, is summarized in Tables 4, and 5. This group division was coherent except two, Ghayda and Ohowed. Ghayda resembled the second group's conceptual structure by thinking that carbon dioxide is used in plant breathing, and in considering energy as particles, she did not however think that plants grow from the division of chlorophyl cells. Ohowed had a unique conceptual structure much like that of scientists in the third paradigm. She knew that carbon dioxide combined with water to form glucose, while at the same time, she thought of energy as substance which adds weight to the plant. When she was convinced, in class that light is almost weightless, she restructured her theory into complete scientific ideas. I chose to put her with Salam in the Third group. Salam believed that carbon dioxide combined with water to form glucose, while thinking that soil has much to do with the body's weight. She also restructured her idea from the first lesson, when she knew that plants absorbed less than 1% from the soil.

Case Studies on Students Entry Level Knowledge

Case Study 1:The source of plant growth

This case study shows how students, with various types of misconceptions, tried to answer questions about the source of plant growth, using their own, often naive, theories. Appendix C explains the goal the researcher was trying to accomplish by the questions asked in the dialogue. The sole intent of the treatment was not to give the information directly to the students, but allow them to make inferences by themselves, so that they would develop understanding that is similar to the scientific one.

The discussion after the dialogue between the students and the teacher, concentrated on how each student from various groups tried to respond. The following quotes are taken from a class discussion responding to the questions asked by the teacher. Not all the dialogues are included, only students' answers that facilitate our understanding of their entry level knowledge are included. The number of asterisks beside the students' name corresponds to the students' group number.

Lesson 1

......T: Why are the sun, the air, and the water important?....

Ohowed***: Light is important. We take vitamins from the sun. We get sick if we are prevented from being in the sun.

Kholowed**: Light is also important in photosynthesis, to take in water and minerals.

Salam***: The chemical compounds are found in the soil, and the plant absorbs them when it dissolves the water in the root.

Basema*: The plant is a factory for a food......

T: How do you explain that soil does not lose much weight to plants as they grow?

Ohowed***: The increase in weight comes from the light.

Kholowed**: The light (repeated it another time after Ohowed).

T: If you want to weigh the light, can you?.

Abear*: But, it affects photosynthesis.

T: Yes, but you do not weigh the light. Still, can you measure how much weight is gained through absorbing carbon dioxide?

One student said in English "no"

T: The water and carbon dioxide can affect the weight of plant. Who can name another thing.

Asma*: If we plant a small seed, it grows from the nutrients inside.

T: Yes, but after a while, to keep growing, plants synthesize food from raw material, it cannot synthesize food from nothing.

Salam***: The water and minerals inside water affect that.....

T: Soil contributes about three grams for every 2000 grams. But, could we neglect it? Can the plant survive without it?

Basema*: The organic material from animals is consumed by the plant.

T: Plants do not consume it while it is still an organic material. It should return it to its original form (inorganic). The bacteria work on that since it uses this material as food.

Abear*: The soil contains an organic material; then it decomposes and there are the minerals.

Basema*: The plant takes carbon dioxide and then releases it....

A question from Fatema: In winter, there are no leaves, while we observe that leaves grow in summer; where does this material comes from? Does it come from the material condensed inside?

T: As long as plants engage in photosynthesis they form food. The new branches do not just come from the stored food of the last summer. ....

Lesson 2

T: Who can make a summary about what was said in the first lesson?

Asma*: We said in the first lesson that water is the essential factor in the body of a plant. Also, osmotic pressure gives the weight. (Asma's answer gave a clear indication about how the information that is related to understanding other subject as physics was distorted by her).

Analysis and discussion: In this dialogue, the teacher tried to make the students discover that the weight of plants does not come primarily from soil. The teacher tried to lead students to consider that carbon dioxide, which combines with water to form organic compounds, is the source of plants' weight.

The dialogue and the pretest results show that only one student came with a naive theory, thinking that the weight of plants come from soil. This was Salam, a member of the third group.

Answers from the other groups of students showed they do not have such naive ideas. They had already restructured their theory from previous studies in school. In the pretest, they used such terms as "soil does not lose weight. Plant takes its nutrition through photosynthesis." How did these students understand the meaning of photosynthesis? Their answers to the primary question about the source of the plant's body illustrates that.

In this discussion, a multiple comparison of various students' conceptual structures is presented. It shows how each group of students tried to answer the teacher's question, using their own, often naive, theory.

The groups to be presented first are those with the a conservation of matter conceptual structure (the fourth and third groups of students). The fourth group knew that plants make food by combining carbon dioxide with water in the presence of the light. This is explained by Fatema's**** questions. After the instruction, she asked whether the growth of plants comes from organic material formed in the previous summer or from that currently being synthesized through photosynthesis. What she understood from the textbook is that plants condense food in the root during the summer. To her, the plants' growth came only from this condensed food. The emphasis that the plant's body grows as long as light is absorbed through photosynthesis, led her to question her own theory. I told her that as long as there is photosynthesis, food would still be produced. Fatema ended up with a strong scientific theory.

Another example of students who held the conservation of matter structure is Salam***. She knew about the photosynthesis reaction, but her understanding was still mixed with misconception. Salam*** thought that photosynthesis is used just to provide the necessary energy that is released through the respiration process, while plants grow only from the soil, as is shown from her classroom dialogue and the pretest. When Salam*** was convinced that plants took just a little from the soil, she changed her theory. She then stated in her homework that soil supplies minerals (which contribute less than 1% of plants' weight), while the major part of plant weight comes from water and organic material synthesized through photosynthesis.

Ohowed*** knew that plants grew as a result of photosynthesis, but still had difficulty in understanding the textbook. She thought that the light was the source of weight. Her theory is illustrated in another part of the dialogue when she said that "we took vitamin D from the sun," not knowing that the sun helps provide the necessary energy to form vitamins, not that vitamins are taken from the sun, which is common word usage in elementary science textbooks. When Ohowed*** was convinced that light does not really have weight, she changed her theory to a scientific one, knowing exactly that the function of light is to form covalent bonds, not a material that adds weight.

Those students shared a common way of thinking, they do not employ vitalistic thinking. They knew the weight of plants should come from outside resources and that plants cannot synthesize anything from nothing. They have correct propositional knowledge, knowing that carbon dioxide enters to form organic compounds, and not just to be exchanged with oxygen through photosynthesis. The first and second groups, on the other hand, understood absorption of carbon dioxide during photosynthesis as a second mechanism of plant breathing during the day time.

The following discussion presents a contrasting picture for students in group one and two. The students who have vitalistic thinking believe plants can synthesize food from nothing but water, or only from light and water. They also have misconceptions in their propositional knowledge, similar to scientists in the second paradigm, who thought that, through photosynthesis, carbon dioxide was used in plant breathing.

When the teacher asked in the beginning of the lesson about the source of plant growth, Basema* responded "plants manufacture food." Her answer is misleading, as illustrated by the answers of other students from the same group. When asked specifically what the plants need besides water, Asma* answered that a plant grows by itself. When told that plants need raw material to be synthesized and that plants would not grow from "nothing;" all the members of the first group, (Abear*, Basema*, and Asma*) began to speak about the importance of organic material. The teacher told them that organic materials decompose, before being available as nutrition to the plant. This answer did not make sense to them. They did not understand the meaning of the word "decompose." However, they spoke about it and repeated it as a technical term, which misled the teacher. One example of misleading words was Abear's* reply, after hearing the teachers' statement, that plants consume organic material from the soil after this material decomposes. Her answers appeared scientific as if she talked about the importance of minerals for the plant, while repeating the teacher's statement about the decomposing of organic material without changing her theory.

The teacher, at the time of instruction, did not know why students in the first group repeated that organic material in the soil is essential for plant's growth. The teacher inferred that they meant the minerals that would be available for the plant after this material decomposed. They were told in the lesson that carbon dioxide and water are part of the photosynthesis reaction, meaning they should consider this source as an essential part to afford the material needed for plant's growth. It was unknown to the teacher that all students in the first group thought, that through photosynthesis, carbon dioxide is used in plant breathing (instead of oxygen during the daytime). These students modified textbook information to match their naive thinking. When questioned about "where do they think the body of the plant comes from?", the answer were "water" and "what plants synthesize through photosynthesis." This appears scientific. However, these students interpreted the phrase that "plant makes food by itself" to mean that plant produces its own organic material from nothing but water. This misunderstanding was obvious by the answers of Basema* and Asma* during instruction. The first group also believed that the organic material formed through photosynthesis, from just water, would return to enrich the soil with fertilizers, which is a vitalistic concept. This must be the reason they insisted during the first, and fourth lesson and in the second question of the pretest that organic materials, not minerals were needed for growth.

In their homework, the entire group (Abear, Basema, and Asma)*, mentioned water as the only source of plant growth and increase in plant mass. In addition, they stated that carbon dioxide is used in plant breathing.

The second group of students had a similar misconception. They thought that through photosynthesis, carbon dioxide was used in plant breathing and the source of plant weight is light. Kholowed** and Sumayya** understood photosynthesis to mean that light gives weight to plants. When Ohowed*** and Kholowed** were told in class that light does not weigh much. Ohowed***, who knows that carbon dioxide is absorbed by the plant to form organic compounds and doesn't have vitalistic thinking, restructured her theory to a scientific one. In contrast, Kholowed** and Sumayya**, who utilize vitalistic thinking about the nature of material in organisms, did not consider carbon dioxide as a molecule that enters the plant to form organic compounds in the body. They changed their primary theory to an even more naive one; that the division of chlorophyl cells, instead of light, is the source of weight (their answers in the homework). They thought that, by cellular division, plants would grow, independent of any raw material absorbed from outside .

What happened to change those students' theory in this way? There are many reasons. One is that they misinterpreted textbook information to match their vitalistic thinking that the source of material that forms an organism's body is different from the material they see outside. In addition, they were under the impression that their theory was scientific; they did not trust the information that was given through instruction. Several times, they were encouraged to challenge what the teacher had said (Case Studies 3 and 4). It also appears that those students did not have a sufficient background in physics to understand concepts such as light (Kholowed's** answer) or pressure (Asma's* answer). The instruction itself did not take into account the students' naive ideas of physics and chemistry. As the case study shows, the emphasis in instruction was on logical reasoning using biological phenomena, not restructuring naive ideas of other related topics such as physics. This was considered "given" information they should have learned in a physics course. The instruction did not strongly enough challenge whether students thought of carbon dioxide as a gas for breathing, or the fate of organic compounds in the soil. There was no time arranged for this discussion, and when these misconceptions became apparent during class, students were corrected with short answers, there was no time arranged to address these issues in depth.

The misconceptions that underlie students' vitalistic thinking often became apparent, as when Asma* thought that plants grow from nothing. This was handled with brief answers such as "plant has to take raw material from outside." It is only through a systematic, thorough analysis of the same students, and others with similar thinking, that the researcher was able to discover that vitalistic thinking and a poor understanding of physics principles caused systematic misconceptions to persist.

Conclusion: instruction was successful with students who lacked functional knowledge and were unable to relate their propositional knowledge of photosynthesis to everyday phenomena. However, the treatment was unsuccessful with students who lacked a good understanding of the core principles in physics and chemistry, that would enable them to comprehend the metaphoric language in the textbook. The treatment was not designed to address such misunderstandings since they were not predicted in advance. The discussion in Chapter 2, Third and Fourth Paradigms shows that advanced development on the scientific discovery of the biochemical activity of the cell was accompanied by advanced discovery on the nature of light, heat and conservation of matter. The treatment, however, concentrated on systematic development of biology, not physics and chemistry.

Case Study 2: The nature of oxidized material

In this case study, some students' answers in Lessons Two and Three are presented. The goal is to understand students' entry level knowledge about the type of material used in respiration. The same procedure followed in the earlier case study was used. Each student's name is marked by one or more asterisk; the number identifies the group the student belongs to.

Lesson 2:

....T: Does the plant engage in respiration during the day time?

Sawsan****: Plants respire always, with or without photosynthesis

...T: Why do we need water?

Basema*: It gives energy, that allows the chemical activity of the cell.

T: Does water give energy? Why do you consider that?

Basema*: Because it forms most of the components of the cell.

T: That does not mean that it will give energy.

Abear*: It could be used as a solvent for compounds.

...T: If we burn the wood, what would be released?

Salam***: Carbon dioxide and water.

...T: Next time I will explain to you why we need light.

Salam***: We need light because when plants absorb light by the photocells in the leaves, it allows the ADP to be converted into ATP, which is used to make the food. (The issue of photocells was not discussed in class. However, it was in the textbook for reading purposes only. Salam was able to grasp the meaning of photocells since she took additional courses in physics outside school. However, many students did not share this understanding. Some believed that organic compounds form by the division of chlorophyl cells.)

Lesson 3

...T: The first material to be formed by the plant is glucose. Suppose we took the plant material and burned it. What are the products released from this burning?

Fatema****: Carbon dioxide.

T: What else?

Asma*: Water vapour.

T: Why do you think carbon dioxide and water vapour will be released?

There was about 20 seconds of silence before Salam raised her hand.

Salam***: Because the material which was used originally to form the carbohydrates, will be the same that will be released.

T: Is anything else released?

Basema*: Heat also would be released.

T: Where did the energy that accompanies burning come from?

Kholowed**: From solar energy, which the plant first absorbed during photosynthesis and has been released by burning.

Salam***: Carbon dioxide, water and ADP will also be produced.

T: This happened inside the body. If the burning had happened outside the body, the energy will go off as heat only.

T: Is respiration important because carbon dioxide will be released during the process?

Salam***: No, it is important because of the energy that is produced during the process.

T: Can any organism live without respiration?

Kholowed**: No, since no organism can live without energy.

<u>Analysis and discussion:</u> The rationale in teaching this topic is to make students know that, through respiration, the material formed through photosynthesis would be released in the form of carbon dioxide and water to give energy and continue life in all organisms.

The dialogue above illustrates one common thing between the first, second and third groups of students. All came primarily with the knowledge that the function of respiration is to supply energy to continue life in all organisms. Salam***, Kholowed**, and Basema* mentioned in the dialogue of the third lesson that energy release accompanied respiration. Also, in the pretest, the students in these three groups mentioned that respiration happens in all organisms, meaning they know how to relate the respiration process to its function. They had good concepts of the conservation of energy. Kholowed**, in the third lesson, and Salam***, in the second, gave answers which show they are cognizant about the conservation of energy.

The analysis shows, however, that only the third group of students came into the study possessing both correct propositional and functional knowledge regarding respiration (Salam***). Salam knew that, through respiration, carbon dioxide, water, and energy would be released, and that this energy is necessary for every organism to maintain life.

Although other students in the first and second groups came into the study knowing that there is a material in the body that is used to produce energy for all organisms to maintain life, they did not know the nature of that material. Those in the first group thought the material was water. They also thought water burned to produce water vapor and energy, as shown in Asma's* dialogue. And those in the second group thought that organic material composed from just energy burned to produce just energy.

The analysis also reveals only one group of students did not begin the treatment with a prior correct functional knowledge about respiration. This was the fourth group of students (Sawsan and Fatema), and the treatment successfully allowed them to make this connection. This group had some initial misconceptions about the functions of respiration. Their pretest answers did not indicate they believed that all organisms respire because they need energy. They still had correct propositional knowledge, knowing that carbon dioxide and water released in respiration process are products of burning glucose. It could be their partial understanding that photosynthesis provides building blocks for the body that prevents them from recognizing that it also affords energy to all organisms. They did understand respiration's mechanism. In the dialogue, Fatema's**** answer indicated she knew that carbon dioxide is a product of burning.

The significant issue in the answers of the third and fourth groups of students is that they understood, well before the treatment, that respiration in plants happens continually, not that plants only take in carbon dioxide during the day and oxygen at night, as the other groups tended to believe. Their propositional knowledge is similar to scientists' in the third paradigm. The answers of Sawsan**** at the beginning of the second lesson prove that. She said "plants respire always, with or without photosynthesis." This understanding could explain the lack of misconceptions that many students in the first and second group had regarding photosynthesis. When the third and fourth groups of students understood how carbon dioxide enters to form organic compounds with water, this allowed them, prior to the treatment, to know that in the photosynthesis process, carbon dioxide not only enters to build the organic compounds, but also part of these organic compounds are consumed through respiration.

The fourth group members were the ones who benefited most from the treatment. As mentioned earlier, although they initially knew that respiration produces carbon dioxide and water, they did not correctly answer that all living organisms need energy for life, meaning they did not fully understand the function of respiration. The treatment allowed them to utilize their propositional knowledge to explain everyday experience. They learned that respiration is not just a procedure used to produce carbon dioxide and water through the reaction of organic compounds with oxygen, but also releases the energy needed for continuing life.

The third group began the treatment with correct ideas about the function of respiration, accompanied by correct propositional knowledge. Salam*** showed that she understood from the beginning that all organisms respire because they need energy, and the carbon dioxide released during respiration is a product of burning organic compounds.

Compare Salam's*** understanding to Kholowed's** understanding in the second group. Kholowed's** in the second and third lessons showed she comprehended the issue of energy conservation. Her answers in the dialogue and pretest showed she understood the source of energy in organic compounds is solar, and every organism respires since they need this energy. However, there is no indication whatsoever, that she knew about the conservation of matter in this process. She didn't know how carbon dioxide entered the respiration process. Her conceptual structure regarding respiration was consistent with her understanding about photosynthesis. All she knew about photosynthesis was that "solar energy is stored by the plant." She did not comprehend the importance of carbon dioxide in the process.

The conceptual structure of the first group differs from the other three groups. Case study 1 shows that those students in the first group believe the body of plants form from nothing but water. This is what they understood from the statement "plant makes food by themselves." They also thought the organic material that forms from only water, could be used to enrich the soil with fertilizers if plants (or animals), which are raised in the same ground are left in the ground. Carbon dioxide was not considered to combine with water to form organic compounds; it is only used in plant breathing. This was evident by the answers of Basema*, Abear*, and Asma* in the first, second and fifth questions of the pretest. In the first question of the pretest, all of them said carbon dioxide is used in plant respiration, meaning they do not understand its function in forming glucose. In the second question, they answered that plants absorb only a little from the soil since all that is needed is the organic material. Thus, they believed that plants grow from organic compounds, not that minerals are absorbed after organic material decomposes. Asma and Basema's answers, during the dialogue in Case Study 1, revealed they believe that organic material formed through photosynthesis from water only. In the fifth pretest question, all of them agreed that planting crops in the fields would enrich soil with fertilizers by bringing organic material formed through photosynthesis "from nothing but water".

How does this understanding about the photosynthesis process relate to their understanding about the respiration process? The answers of the first group in the pretest show that they believe that all organisms respire because they need energy. Basema* mentioned in the second lesson that heat is a product of respiration which means they understood that respiration produces energy needed by all organisms. Does their understanding of the function of respiration mean they understand the process? The answer is no, depending on their conceptual structure. If their concept was that organic material, "which forms through photosynthesis from nothing but water", is a building block for the body and returns to enrich the soil with fertilizers after death, then they believed that water is the material used for burning and supplies the body with energy. In the sixth question of the pretest, all members of the first group said that water is the material used to produce energy. These data reveal their coherent misconceptions regarding the issues of photosynthesis, respiration and ecosystem. Basema*'s response during the dialogue is consistent with the data; she said water is the material used in burning. During the lesson, Abear* appeared to understand the function of water; and even though she did not, she gave the same answer as Basema* in the pretest. After observing what Basema* was told during the lesson, she answered that water was used as a solvent, which is correct; but her answers in the pretest showed she believed that water was used as a solvent and to provide energy. To add to the difficulty of interpreting her concepts, Abear's * defensive way of answering questions during the lessons made it difficult to infer what her conceptual structure really was.

According to the first group, if water is the material used to provide the energy released through respiration, then what is the product of such a mechanism? The answer is water vapour. This was demonstrated by Asma's answer during the dialogue.

The case study also explained why students in the first, third, and fourth groups chose the lungs and skin as a place for respiration (Table 4). They understood the location of respiration to be where the product of respiration was released. The first group chose lungs and skin; lungs for breathing, skin to release water vapour burned through respiration, implying that water, not organic compounds is the source of energy. The second group did not choose skin. To them, energy can be released many ways, while lungs accompany the breathing process. The third and fourth groups chose the lungs and skin. Lungs to release carbon dioxide, skin to release water. This rationale for choosing lungs or skin is my inference, based on what I know from the conceptual structure of various groups of students. The idea that respiration happens in every cell was not mentioned by these students in the pretest.

Conclusion: This case study illustrates how the entry level knowledge of students regarding respiration, would affect the way they restructure their theory. The treatment was successful in treating the misconceptions which resulted from lack of integration of the historical questions regarding the function of respiration to the correct propositional knowledge of the students. Only one group of students came to the study with this conceptual structure (Fatema and Sawsan in the fourth group). Although both students primarily came with a good understanding that organic compounds decompose in the form of carbon dioxide and water, neither student connected that to the function of respiration to release energy condensed in organic compounds to allow continuing life in all organisms. The treatment succeeded in making them understand that function. The third group of students (Salam and Ohowed) already had a good scientific theory regarding this issue. Six out of ten students remained. The instruction passed over their misconceptions. It never dawned on the teacher, throughout instruction, that some students thought organic material would only be energy. This was implied in the students' answers, but the teacher (researcher) did not pay attention to this point until after instruction was completed and data analysis was in progress.

In the treatment the teacher was misled, since students already possessed a scientific theory, on the surface level, regarding the function of respiration. Students knew that the energy stored in organic material was released by respiration. However, there were misconceptions in their propositional knowledge. Kholowed's** answer revealed she had good scientific theories, on the surface, about the function of respiration, but she still never mentioned that carbon dioxide was a by product of such a process. The discussion in Case Study 3 revealed that many students did not relate the burning of organic material in the body to the breathing process, since they thought that these were separate processes. When those students continued to think of organic material as a type of energy, although separate from the breathing process, then all discussion about decomposing organic material into carbon dioxide, water, and energy would be irrelevant information to them.

I suggested that to help students who have such conceptual structure reorganize their theories, the primary step should be to make students know what the term "organic compounds" really means, and how they form, using physical and chemical concepts through discussion.

During the dialogue in class, the instructor discovered that the first group thought water was the material to be burned. The instructor tried to make them understand that it is organic material that is burned, but this was not effective. Another serious misconception about the nature of organic material was not recognized and was not corrected, because even when those students restructured their ideas and accepted organic material as the material that is burned to release energy, they still thought that these organic materials are formed from only light which was later decomposed in the form of energy through respiration. The students misunderstood the textbook information about food, which, by using metaphoric language that food means the energy condensed between organic bonds, led students to think that plants were formed from just energy.

The treatment was effective in students who began with an insufficient understanding about the function of respiration. Those students initially possessed correct propositional knowledge regarding the fate of carbon dioxide and conserving of matter. The treatment failed to correct the first and second group's misconceptions to enable them to see that organic material does decompose to produce carbon dioxide and water and release energy. The instructor was misled by students' correct answers about the function of respiration, when they still lacked propositional knowledge about the respiration process.

The students' responses in Case Study 3 were aimed at understanding why students did not know that respiration took place in the cells. This will be discussed next.

Case Study 3: Location of respiration

The third case study analyzes how students understand the function of oxygen in the respiration process and where they believe this process leads.

This case study is part of lesson three. It includes most of the conversation with students in the second half of this lesson. As in prior case studies, students names are marked with asterisks. The number of asterisks denote which group that student belongs to. Students' answers were affected by what they learned from the instruction in case study two.

Lesson 3:

...Salam***: If our body is full of organic material, which means that it is a storage for energy, why would we die without oxygen?

T: Suppose you see a big fire, with many burning materials. What will you do to stop the fire? You simply try to prevent the oxygen from reaching out, in this way the fire will stop immediately.

Salam***: But there is an ATP in our body to afford energy. (Her answer implied that she did not think oxygen is needed in the respiration process in which ADP is changed into ATP by condensing the energy released by decomposing organic material).

T: If we prevent the oxygen from reaching the body, there will be no more ATP to supply energy for the biochemical activities inside the body, and then the body will die.

Salam***: Does our body need the energy inside, besides outside (for external activity)?

T explained the chemical activity which allow many reactions to happen inside the body

Kholowed**: Does Salam's*** question mean that if we do not respire we would die, because the oxygen does not reach the brain, and the brain is the one which decides the order of respiration?

The teacher explained that brain cells are more sensitive because the cells have lost the ability of division, to produce new cells to replace the ones affected by less oxygen. The nucleus in the other cells of the body are still active to replace cells that have dies, whereas, nerve cells have lost the ability to reproduce themselves.

Abear*: When we breathe, the blood carries the oxygen into every cell of the body in a fraction of a second. Does this mean that this entire process of burning happens every time the blood carries the oxygen in and out?

T: It happens, as long as the heart pumps blood into the cells.

Kholowed**: Sometimes the heart beats faster.

T: When your heart beats faster, it works to get more oxygen because the body needs more energy.

Salam***: When the brain dies and the heart still lives, does this mean that the heart does not supply any more oxygen to the brain.

T: Even if the oxygen reaches the brain (after temporary blockage), it is useless since the cells have died permanently. There is no way to renew others for the nucleus in the brain cells has lost its ability to renew the ones which had been damaged by the lack of oxygen.

Abear*: Here, they gave other healthy organs to another person.

...T: Where do you think this energy that is released through respiration comes from? (This is not related to what students began to contextualize. They began to tell stories of how the brain of a mother died and the doctors kept her body a live to give birth to the baby. the teacher tried to return them to the subject at hand).

Basema*: From the carbohydrates, when it burns, it releases energy by reacting with carbon dioxide. (Initially the teacher missed the misconception, thinking that Basema said the reaction of oxygen with carbohydrate. Only the audiotapes reveal the mistake).

Salam***: If we supply the body with ATP where the burning happens, could this replace oxygen?

T: We cannot replace oxygen with something else. The ATP forms from the energy released after oxygen reacts with glucose. (The teacher did not pay attention to Salam's erroneous inference that there is a special place in the body where burning continues.)

Kholowed**: There are 38 ATP released from material that forms through photosynthesis that don't affect breathing or need oxygen (she is referring to anaerobic respiration). Only 2 ATP are used with oxygen.

T: No, the reverse is true. These 38 ATP form from oxygen, only 2 without oxygen. (The teacher was not cautious enough, unaware that Kholowed didn't know that the same organic material from photosynthesis was used in both processes of respiration).

Analysis and discussion: The teacher in this lesson was trying to make students understand the process of respiration by making analogies of the burning of organic compounds outside the body, in which they react with oxygen to produce water, carbon dioxide, and energy. The teacher also tried to make students understand that a similar process happened in every cell of the body.

All students, regardless of their primary theories about respiration and photosynthesis, began the treatment with naive ideas about where respiration happened. They either mentioned the skin or the lungs as the place where the process of respiration occurred. None of them knew, that through respiration, oxygen is needed to react with organic material.

At the beginning of the dialogue in the third lesson, the teacher tried to relate the function of respiration to the burning process. Salam***, who knew on the surface that respiration had something to do with burning organic compounds to produce energy, asked why it should be necessary to use oxygen in respiration, wasn't organic material enough? The teacher, who didn't understand the question completely, told her that oxygen is the gas which activates the burning process. If this gas was prevented from reaching a fire, the fire would stop. When Salam*** continued arguing that there was ATP there, the teacher didn't understand why Salam*** thought ATP would replace oxygen. Kholowed's** answer interjected what Salam*** meant. Kholowed** implied that if "energy could be released from the organic compound formed through photosynthesis, why is it necessary to use oxygen in respiration?" Another covert meaning for Kholowed was that "respiration by oxygen, does not need organic material to act on. Kholowed thought the oxygen in breathing process does not act on organic material." Although Kholowed did not recognize that oxygen reacts with organic compounds and the organic compounds are the ones converted to carbon dioxide and water. The teacher still did not recognize her misconceptions, the teacher simply thought that Kholowed** was talking about anaerobic and aerobic respiration. Kholowed** was really talking about the process of aerobic and anaerobic respiration, but did not understand what the process means. Even when she talked and used terms that implied misconceptions, the teacher only heard what Kholowed** understood about the process, not what she did not understand.

Although Kholowed** thought that the breathing process has nothing do with the organic material, this does mean that Salam***, to whom Kholowed*** referred, had the same conceptual structure. Salam***'s answers in the previous case study proved she knew that carbon dioxide is a by product of burning organic material in the body, not just a result of exchanging gases with oxygen. Her question simply meant if there is ATP released during anaerobic respiration, why do people die from lack of oxygen." Her question was answered in detail in the sixth lesson explaining that anaerobic respiration does not release all the energy needed by human beings.

Salam*** and Kholowed's** theories that oxygen has nothing to do with the burning, accompanied another misconception, that there is a specific place in which breathing happens. Salam*** thought the process occurred in the brain, saying "it is the organ which is affected by lack of oxygen."

Because their misconceptions were not unique, detailed illustrations about the function of respiration were given to Salam*** and Kholowed**. Students with various conceptual structures had the same misconception about the role of oxygen and where respiration happened.

Abear*'s answer that the function of blood is to carry oxygen to every cell is misleading. Following the argument with Salam and Kholowed, she realized that oxygen is carried out by the blood. She did not really know the details of the process, since she did not understand the nature of organic material to be burned. Although she gave an answer that reveals good inference, saying that respiration happened every time the heart pumps the blood in and out, she lacked enough information about the subject to make her confident about her inference. She did not know the carbon dioxide that is released in breathing is a product of the decomposing of organic compounds. In the fifth lesson, she returned to say that burning could happen in the liver. She replaced her own inference with what she suspected the scientists' answer would be. Asimov (1977) told a joke about a similar incident in which a teacher was trying to teach one of the French royal family some scientific issues through inference. The prince was never sure of his own answer, until the teacher told him this is what scientists said the answer should be. Then the prince said "now I get it." The teacher told him he should know there is no royal authoritative passage for learning and he should get the concept through his own inference.

The way the first and second groups understood respiration is explained by Basema's* answer that carbon dioxide reacts with carbohydrates to give energy. Basema* thought it was either oxygen or carbon dioxide that reacted with organic material to produce energy. Unlike Salam*** (in the second lesson), she did not understand that carbon dioxide was a by product of the reaction. She thought that carbon dioxide reacts with carbohydrates to produce energy. The problem is that the teacher was not cautious about Basema's* meaning. The teacher thought Basema* said that oxygen reacts with organic material to produce energy and carbon dioxide, that the students' answers logically followed the previous class discussion. The teacher was unaware that students' understanding of the topic was based on their preconceptions, instead she heard them according to her own conceptions. The theory of Basema* and probably all the students in the first and second groups (Abear*, Asma*, Kholowed**, Sumayya** and Ghayda**), did not change a lot. When the teacher corrected Basema* in the second case study, telling her it was the organic compounds, not water, that burned, Basema* replied that carbon dioxide reacts with carbohydrates to produce energy.

Conclusion: This case study also stresses what the first and second case studies concluded. Students' entry level knowledge affects what they learn from instruction. Although all the students came to the study with naive ideas about the function of oxygen, the treatment proved most effective with students who already had correct scientific propositional knowledge about the nature of organic compound and the product of burning. Students in the third and fourth group (like Salam***) did reorganize their theory to accept that oxygen reacted with organic material to produce carbon dioxide, water, and energy.

The dialogue reveals that while, on the surface, the treatment was effective in teaching the first and second groups to accept that burning happens in every cell, this comprehension still contained serious misconceptions. When those students were given scientific information, they tried to distort the information according to their own theories. They believed that through anaerobic respiration, the organic material formed from photosynthesis would burn, while aerobic respiration only accompanies breathing, which means they do not understand that carbon dioxide in breathing is a product of the burning organic materials formed in photosynthesis. This is understandable, since all of them equated organic material and energy, and carbon dioxide had nothing to do with forming organic material through photosynthesis. Carbon dioxide was thought to be only for plant breathing during the day time. The fact that oxygen reacts with organic compounds had no meaning to them. For them, it was simply carbon dioxide or oxygen that reacts with organic material (Basema*'s answer).

The teacher failed to recognize these misconceptions in the students' dialogue during the lesson. This became obvious when listening to the audiotapes. Perhaps if the teacher had caught these implied misconceptions during instruction, students would have been aware that carbon dioxide is a part of the organic material and does not react with organic material.

Students' Conceptual Change Through Instruction

In the previous section, the entry level knowledge that affected students' reasoning were examined by analyzing students' answers in the pretest and the dialogues in Lessons 1-3. The same issues discussed in earlier case studies will be discussed here also, but the emphasis will be on if, and how, they changed their earlier ideas.

Case Study 4: The plant growth

At the beginning of the fourth lesson, the goal was to examine how students understood the function of photosynthesis, eventually making them understand the importance of soil.

Lesson 4.

T: Where do you think these new branches and leaves come from?

Asma*: From the material that was stored in the winter. When the spring comes, this material is released as new branches and leaves.

Basema*: From the sun, during photosynthesis.

T explained that organic material would be produced as long as there is photosynthesis. (The teacher did not catch the misconception implied in Basema's sentence when she omitted reference to carbon dioxide and water).

Returning to my original question Fatema**** asked: Is the series of starch composed from glucose?

T: Cellulose and starch are both composed from a series of glucose.

T: Does the building of the cell come from carbohydrates?

Kholowed**: We need minerals also.

T: Does this extra material contribute to so much weight.

Basema*: No, because most of plant weight comes from water.

T: Also, the plant absorbs carbon dioxide.

T: What types of material do all the plants and animals need? (The teacher meant nitrate for synthesizing plants' protein).

Asma*:Minerals, organic materials, and some chemical fertilizers. (It appears she thought minerals and organic fertilizers are needed for different purposes. She did not know that people used organic fertilizers because minerals return to the ground after these organic materials are decomposed).

T: What type of fertilizers do plants always need? (The teacher meant nitrates for protein).

Asma*: The natural ones (animals' waste) are better.

T: Why do you think so?

Basema*: We have some land which gave a very poor yield of wheat. We gave the land to some people to use. They planted tobacco for two years and returned the leaves of tobacco to the same land. When we planted wheat after those two years, the land gave a larger yield of wheat, which means that planting tobacco made the land richer and more suitable for planting wheat.

The voice of Asma* and Abear* in the recorder indicate that they agreed with Basema.

T: What you said about tobacco and wheat did not mean that tobacco would make the soil richer. It could be that the minerals were deep under the surface of the ground where the roots of the wheat cannot reach. But when you planted tobacco for the root of the tobacco was more successful in absorbing these minerals, and when you left the leaves of the tobacco in the soil, these minerals became more easily available to the root of the wheat to absorb. (the teacher -researcher- inferred the reasons during the lesson, taking the student's experience as true, however through the researcher readings after that lesson, it was found that there is a historical case in Virginia; the land became arid at the end because the farmers had used this practice without refertilizing the land).

Analysis and discussion: This lesson was arranged primarily to help students understand, specifically, the role of minerals in the soil in forming the body's tissue while connecting that to the function of photosynthesis. However, as shown here, if students still did not know the nature of organic compounds, in spite of the instruction in the first and second lessons, then discussing the role of soil would be useless. This dialogue stresses the conclusions from the first case study, that the students' entry level knowledge (conservation of matter and vitalism) affected what they understood from the treatment.

A general overview of the dialogue shows that students who previously employed conservation of matter and correct propositional knowledge, knew that, through photosynthesis, carbon dioxide combines with water to form glucose. This is the initial formation organic compounds. Those students were able to comprehend and integrate the information about how glucose is synthesized and reformed inside the body (Fatema's**** dialogue). In the dialogue, Fatema**** asked if starch is composed from a series of glucose. This means she well understood how organic material is formed. Comparing Fatema's **** to the answers of Asma* and Basema*, Asma* gave a general answer, saying the material is stored through photosynthesis without being specific, while Basema* thought that this material is formed from the sun.

Fatema's**** and Sawsan's**** reply to the question on the second homework about the source of new branches in the spring, was that they come from the material condensed from the previous summer and what the plant is currently synthesizing. This proves both finished the treatment with a complete scientific idea regarding this issue.

Salam*** also ended the study with a scientific idea. She explained in the homework and the posttest that carbon dioxide and water react to form glucose. She considers that food is used to build the body's tissues. Ohowed*** also had the same idea in the end.

While the third and fourth groups finished with relatively complete scientific ideas, the second and first groups, who initially employed vitalistic thinking from the second paradigm, changed little.

In the second group, Kholowed** was convinced in the first lesson that light is weightless and changed her idea to include chlorophyl and water as the source of weight. She still thought that carbon dioxide was absorbed in plant respiration, instead of as oxygen as in animals. The instruction in the first and second lesson about photosynthesis also did not substantially change Sumayya**'s theory. She just concluded that the division of chlorophyl cells, light, water, and carbon dioxide were the source of plant's growth. She did not know that carbon dioxide is used to form organic compounds when combined with water.

This means that those students in the second group, beside, maintaining the same propositional knowledge common to the scientists in the second paradigm, still held the vitalistic belief that plants could grow through cell division independent from outside inorganic material. They did not know that cell division itself needs material from outside.

The second group's conceptual structure differed from the first group in that they did not think that planting crops in the field would enrich soil. Kholowed answered, in the lessons and the tests that she believes that plants compete with each other to get what they want from the ground. This was similar to Leibeg's explanation.

The students in the first group changed their ideas only a little after instruction. Their explanations show they still retained propositional knowledge from the second paradigm, in addition to maintaining their vitalistic thinking. They interpreted the textbook words "plant stores food between the organic bonds," to mean the body of plants form from water and energetic bonds. The answers of Asma* and Basema*, at the beginning of the lessons, gave a hint about that, while their answers in the homework after the second lesson gave a specific and explicit idea about the nature of misconception. All of them mentioned in their homework that the weight of a plant comes from energy stored between hydrocarbon bonds. Their answers to the first question of the posttest indicated they still thought that carbon dioxide was used in plant breathing in the day time, while plants used oxygen for breathing at night. As the dialogue indicates (Basema*), they still thought planting crops would enrich soil with fertilizers, and did not mean legumes, because the questions stated that beans were planted after the grains.

Conclusion: Earlier discussion shows that the instruction was effective only on students whose preliminary concepts allowed them to appreciate what was said during the instruction. The students in the third and fourth groups had, from the beginning, correct propositional knowledge about the fate of carbon dioxide.

The treatment was not effective on students who used general textbook terms to support their reasoning for the phenomena that matched their vitalistic thinking. This behaviour masked their misunderstanding for the textbook's propositional knowledge. This misunderstanding was hard to discover, but revealed through instruction. As I said before, the textbook statement "plants store food inside organic bonds" was understood by students in the first and second groups that the weight of a plant comes from energy stored between hydrocarbons bonds. This naive theory was reinforced by textbook conceptualization, which stressed the function of food as affording energy only, without emphasizing its function in building tissue. The first group maintained vitalistic thinking, believing that plant would add something to the soil.

If the teacher was aware of the vitalistic thinking behind the first group's argument about the importance of organic material, she could have engaged them in deeper discussions about the nature of organic material. For example, the teacher's argument shows that she took for granted that the students understood conserving of matter, while the first and second groups answers did not reveal such concepts in their argument.

Case study 5: Respiration process

This case study revealed how students' concepts, from a variety of levels was reshaped at the end of the instruction. It shows how information was distorted in some groups, and how it was used to form scientific ideas in others.

The case study contains dialogue from lessons 5 and 6. Those lessons were arranged primarily to discuss the detailed process of respiration and the role of enzymes and ATP in the process of oxidizing organic material inside the living organisms. This discussion depends upon students' primary understanding about what was discussed in the second and the third lessons. Most students did not gave answers to reflect their level of understanding about the issues. Deep analysis of their discussions shows they have serious misconceptions about the nature of energy which makes their understanding of the respiration process very difficult.

Lesson 5

T: What happened to the material the baby chick had eaten?

Abear*: Some of the material had converted into energy, and the others used to build body tissue.

Basema*: The food converted into glucose for respiration, while the others are wasted.

Lesson 6
T: How would the brain control the respiration process?

Sumayya**: By the skin; it gives the orders to open and close the openings in the skin.

Fatema****: The energy is distributed to all parts of the body equally, and the extra energy would go out through the skin with sweat.

T: What prevents the body's temperature from becoming equal to the temperature outside?

Abear*: The nervous system controls the process. If the temperature outside is low, it orders the burning of more foods. But, if the temperature outside is high, it orders the opening of the skin to remove the extra heat.

Analysis and discussion: The dialogue reveals fundamental differences between students who conserve matter and those who are vitalistic in their thinking, regarding their understanding of the process of respiration. Specifically this reflects their differences in understanding physics principles.

Fatema's**** answer, in the sixth lesson, indicated that she knew that the openings in the skin allowed the release of water and salt. However, the transfer of energy depends on vaporization of water, not that energy needs openings in the skin to go out.

Compare Fatema****'s answer in the fourth group to the vague answer of Sumayya** in the second group or the answer of Abear*, who thought that the skin opens and closes allow energy to enter and leave. Abear didn't know that energy does not need openings to go out, it is the sweat that needs these openings. Kholowed** said in her homework that food changes into energy. Sumayya** stated how many kilocalories were lost in this process, but she equalized kilocalories and kilograms. The textbook gave an example of how many calories one gram of glucose gave; many students thought that glucose changed into calories by burning.

The first group had a conceptual structure that resembled that of the second group. Abear's* statement in the fifth lesson indicated her belief that food changes into energy. Her dialogue in the sixth lesson reveals she thought energy was a substance that needed to go out openings in the skin. Basema* gave similar answers in her homework, mentioning how many calories were lost for every gram. She also had more serious misconceptions, thinking food was either for respiration or eliminated, not mentioning the function of food to build the tissue. Asma* also said in her homework that food changes into energy.

This indicates that those students in the first and second groups held the same theory of scientists in the second paradigm who viewed heat as any substance. The history of science shows that overcoming this misconception was necessary to understand what photosynthesis and respiration are (Lanham, 1968).

Conclusion: It appears that only the students in the third and fourth group understood the topic well. These students had sound propositional knowledge from the beginning. They knew how food was metabolized and eliminated in the form of water, carbon dioxide, and energy. The first and second groups demonstrated misconceptions about the nature of matter. They thought that energy needed openings to be released. They equated matter with energy; this idea characterized their other misconceptions in photosynthesis, ecosystem, and respiration. Those students did not succeed in acquiring scientific ideas in any topic under study and their misconceptions tended to be coherent given the premises from which they were reasoning.

Discussing prerequisite physical information of the topic, was not accounted for in designing the treatment, although this was a prerequisite in developing the scientific theory in the biochemical activity of the cell of the history of science (Lanham, 1968, Kuhn, 1970). It could be that some of these reasons were behind the failure of the first and second groups to reach acceptable scientific concepts about the issues in this treatment.

Integration of New Information and Entry Level Knowledge.

The remaining question is related to the theory from which the research was derived: What are the individual cognitive differences between students who succeeded in restructuring their theory and those who did not.

Case study 6: Students' reasoning through instruction

Students' reasoning through instruction were used to examine the relation of the type of reasoning students gave to their entry level knowledge and their comprehending of the subject matter.

This dialogue is not in a logical sequence. It was pieced together from the dialogues that show the nature of students' scientific inference. The asterisks that accompany each name refers to the group the student belongs to.

Lesson 1:

T: Why in the history of science, were scientists not able to repeat Priestly's experiment?

Abear* and Sumayya**: Maybe they repeated it when there was no light.

Lesson 3:

After the teacher discussed the need for oxygen in burning food:

Abear*: Does this mean that all these processes happen every time we breath?

Lesson 5:

T: A scientist brought a dog and fed him meat only for a while. The scientist killed this dog, and opened his stomach to see where this burning process happened. The scientist was then surprised to find much glucose in the hepatic vein, although not in the intestine. What do you think scientist might have concluded from the experiment?

Basema*: The conclusion would be that the liver can convert the protein into glucose.

Lesson 6:

T: What is the difference between burning outside the body and inside?

Abear*: In burning the wood outside the body, the quantity of oxygen that enters the burning process is uncontrolled, while in the body, there is a definite quantity of oxygen that enters the process of respiration. The quantity of oxygen that enters the process is controlled by the brain.

After the teacher discussed the process of anaerobic respiration
T: Does this process of respiration give off the same amount of energy that human respiration gives?

Abear*: Our body is more complex. We need more energy, while that type of respiration is enough for small organisms like bacteria.

Basema*: If we add a little bit of sugar to vegetables when we begin making vinegar, this will accelerate the work of these microorganisms with such food.

...T: When we make yogurt, why do you think we boil the milk first before cooling it down and adding the old yogurt?

Abear*: If we boil it first, we get rid of the other microorganisms. We will only have the microorganisms produce the yogurt that we added when we cool it down.

Lesson 7:

T: After speaking about the connection between the work of DNA and enzymes, the teacher asked the students "Why does the second generation of organism change its feeding habits after scientists emit X -rays on its spores?"

Basema*: X rays affect the chromosomes, which lead to permanent change in the behaviour of the second generation.

T: I want to know the reason explicitly and specifically, following the systematic way I explained it to you, not just repeating the textbooks words.

Abear*: Glucose is important for biochemical reactions, but we still need another things.

T: It looks as though you were not really attentive to what I said before.

Sawsan****: DNA has changed its order now.

T: Which means?

Sawsan****: That it is not producing the same enzymes as before.

T: Which means?

Sawsan****: Different reactions happen.

<u>Analysis and discussions</u>: Much of the data above shows that students in the first and second groups were able to make good inference when the specific related information was given. For example, Abear* and Sumayya** correctly reasoned that scientists were not able to repeat Priestly's experiment because they repeat it in a dark place. In the history of science, scientists did not know that photosynthesis happened only in the presence of light; so they were unable to reproduce what Priestly claimed because they repeated their experiments in a dark

place. Priestly himself could not repeat his experiment because he was not aware it was initially performed in the presence of light.

Abear* also deduced correctly, after the teacher spoke about the role of oxygen in burning foods, that burning of organic material should happen every time we breathe. She also deduced correctly that to control the amount of heat produced by respiration, the quantity of oxygen that enters the body to burn food should be controlled. She gave correct reasoning that an aerobic respiration did not happen in many organisms because their bodies were big and engaged in more activity; leading to the belief that the quantity of energy produced by anaerobic respiration, is not sufficient for bigger organisms. She also reasoned appropriately that we boil milk first while making yogurt, in order to get rid of other microorganisms. Basema* made a good deduction after the teacher discussed Bernard's experiment on the dog, that the liver, specifically, is the organ responsible for producing glucose from peptides. She also appropriately reasoned that adding sugar to pickles would accelerate fermentation.

All these above examples show that students who failed to restructure their theory had in fact reached the stage considered by Piaget to be one in which students consciously are aware of their own theory and can discuss and reflect upon their thoughts with others. Those students have a stable theory, their theories in all topics appeared to be coherent in the same way as scientists of the earlier centuries. However, they still had many sophisticated, naive ideas similar to these old scientists.

What was missing in those students who failed to restructure their theories is integration of correct information. As the earlier case studies indicate, students' primary thinking that organic material is formed only from absorbing light, produces systematic misconceptions regarding their understanding of respiration and the ecosystem (they do not know how organic compounds are decomposed). When those students think that organic material is formed from the hydrocarbon bonds, then it is understandable why they would think that this organic material would be burned to release energy only.

When vitalistic students such as Basema* and Abear*, were asked in class to make inferences about some specific facts, they were able to do so. But when the teacher asked them to justify the function of DNA, the reasons for the variation in feeding habits and adaptation from one species to another, which requires integration of correct information from the basic principles of chemistry, they responded with general, irrelevant answers. Only Sawsan from the fourth group was able to do so.

Correct, systematic integration of propositional and functional knowledge about various relative issues, is the most important factor in understanding the more advanced discoveries of the twentieth century. Full understanding of twentieth century theories is what Piaget used as a criterion for reaching the final stage of scientific reasoning --formal operational stage (Carey, 1982). This also requires that students reach the upper right end of the U shape as discussed in the first chapter. The example of students' dialogues about the function of DNA show that one student, Sawsan****, had such a way of thinking while Basema* and Abear* lacked such a way of understanding. Internalization and real comprehension of the issues of photosynthesis and respiration also need a systematic consideration of correct information, which means that most students who understand this subject enough to reflect on it, had most of the criteria that Piaget set as an advanced stage of scientific reasoning.

One element still needs to be cleared. In comparing the entry level knowledge of students in physics and chemistry, regardless of what had been obtained in this study, it was found that all students who succeeded in restructuring their theory (except Fatema**** who used to speak enthusiastically about how much she enjoyed studying biology), took advanced courses after school at a nonprofit organization. This organization only accepted students who were high achievers in physics and chemistry. Also, it was found that all students who failed to restructure their theory (except Abear* and Ghayda**) were not taking such courses. This could emphasize my conclusion that a full understanding about the revolutionary theories regarding the biochemical activity of the cell, in the same way contemporary scientists understood, needs a prerequisite understanding about the basic principles of physics and chemistry. This understanding of the basic principles of chemistry and physics was a prerequisite to our contemporary understanding of this issue (Kuhn, 1970).

CHAPTER VI

CONCLUSION

Summary

Many of the misconceptions identified in this dissertation were identified in previous studies too. The presence of functional knowledge in students that differs from the scientific point of view identified by Anderson and Smith (1986). For example, students believe the weight of a plant comes from soil or water. Wandersee (1983) also shows that students believe the weight of a plant comes from soil and water, and that plants add something to the soil. Bishop et al. (1985) showed that learners equated respiration and breathing.

Students' misconceptions in propositional knowledge were identified by Treagust and Haslam (1986), who discovered that students believe that carbon dioxide is used in plant breathing, and that chlorophyl is responsible for plant growth. Smith and Anderson (1986) identified students who believe that food converts into energy. Wandersee (1983) showed that some students believe that organisms form from energy. This misunderstanding was found to persist in students in higher grades.

The previous research on this topic also emphasized the characteristics of the learner and his entry level knowledge as a reason for unsuccessful learning. Anderson and Smith explained that students' functional concepts work as a barrier to understanding scientific concepts. This was tested on students at younger age. These naive ideas held by students were experimentally testable. For example, it was possible to conduct an experiment which determines if soil is the source of weight. Wandersee (1983) and Treagust and Haslam (1986) examined students' conceptual structure at various developmental stages. None of these studies examined how sociocultural factors from previous formal schooling could influence students' naive theories.

This dissertation also shows that students' misconceptions tend to be coherent. The same student was examined longitudinally through seven lessons over a period of four weeks instruction, to see how each concept that was taught related to the others. Discussion during instruction attempted to relate concepts, while using both types of questions (e.g., ones that elicit propositional knowledge and ones that elicit functional knowledge). This allowed the investigator to discover the interconnection of all the concepts that underlie the biochemical activity of the cell and the presence or absence of functional and propositional knowledge in the each student.

Another related finding, besides the tendency of students to have coherent conceptions about the related topics that underlie the knowledge of the biochemical activity of the cell, is the ability of students to consciously explain and rationalize their ideas about every day phenomena (see their dialogue in the Case studies). This means that they reached the stage of developing a stable theory, as described by Piaget.

However, the study shows that six students classified in the first and second groups were still unable to reach a good understanding of the contomporary scientific theory, even though the students were in the eleventh grade, and were aware of their theory and restructured it according to what made sense to them in the textbook and from empirical findings discussed in the class. Those students (in the first and second groups) were able before instruction to relate everyday biological phenomena to scientific concepts. They had already restructured their early, spontaneous, naive theory according to the functional scientific concepts acquired from early textbook learning. However, they still held erroneous propositional knowledge. This type of knowledge, which tends to be abstract, needs a basic understanding of the fundamental principles in chemistry and physics.

The treatment was effective only in the third and fourth groups of students who had a notion about conservation of matter and found the rationale for the treatment matched their thinking. Those students succeeded in integrating their information about the functions of respiration and photosynthesis in the way the researcher intended.

Analysis of students' theories in the third and fourth groups show they tended to be able to reflect abstractly on their theory. This was compatible with Piaget's characteriztion of the formal operative stage of cognitive development. An example of that is found in Case Study 3 when Salam questioned the need of oxygen in respiration, if the energy could be released anyway through anaerobic respiration. Contrasting this with the way Kholowed understood the textbook's information, Kholowed modified what the textbook said about respiration to match her naive theory about photosynthesis. She gave what appeared to be knowledgeable scientific information about the function of respiration, but on analysis it was discovered that she did not really understand the propositional knowledge presented in the textbook. She modified the information to match her naive theory. Sawsan's**** dialogue, which contrasted with Abear* and Basema* in Case Study 6, gave a clear indication that the first group of students were unable to follow the reasoning that composed the many logical steps needed to illustrate the function of DNA, while Sawsan**** was able to do that.

These findings suggest a question of why those students in groups three and four had a good ability to reflect abstractly on their own thinking and have coherent theories regarding their propositional knowledge of chemistry and physics, but still had naive ideas in their functional knowledge before instruction. Another related question is why those who had not reached the stage of reflecting abstractly on their thinking were able to generalize their knowledge to explain everyday biological phenomena but could not reason accurately regarding propositional knowledge. The discussion that follows might partially illustrate the reasons.

According to the findings in this research, the first and second groups' erroneous ideas were similar to rather sophisticated ideas that appeared in the history of science. These naive ideas are mostly in propositional knowledge, such as carbon dioxide is used in plant breathing, and energy is a material. It was apparent that students did not develop these ideas spontaneously. They were formulated from previous readings in the textbook, and from what they learned from others both inside and outside schools. Once those students stabilized these misconceptions, they were hard to alter through instruction, since the misconceptions already looked scientific to them. Students often explained the metaphoric language of the textbook in a way that matched their own vitalistic thinking.

The lack of modification of these concepts by students, even after instruction, arises from the combination of the following factors:

1. Their concepts work satisfactorily. These students scored higher on the pretest in functional knowledge than students in groups three and four.
2. They are adept at giving only enough information to the teacher (and perhaps to themselves) at any one time to avoid exposing flaws in their thinking. Thus, their erroneous fundamental premises are not challenged.
3. The information presented in the textbook is modified by them to match their thinking. Thus, their naive ideas are reinforced by new defined information. Again, foundational premises are not challenged.

This research found, however, that reaching the final operational stage by Piaget "being able to mentally test the ideas and reflect upon it," did not guarantee that students would be able to generalize their information, on their own, especially with the revolutionary types of science concepts. Carey 1984, cited that even many university students were not able to do that on their own even after instruction. It was shown in this research that high school students in the third and fourth groups were not able to do that, if they depended on conventional curriculum alone. However, there was a great improvement with treatment. What I infer here, is that if the kind of functional knowledge that students at this stage are asked to acquire was not consistent with what they understood from all other sources such as their previous understanding about the basic principles of physics and chemistry, it would be too difficult for students to generalize their understanding to explain everyday biological phenomena. Students in the third and fourth groups, who understood well the basis of contemporary principles of physics and chemistry, cannot generalize this understanding to biological phenomena, using biological principles postulated two hundred years earlier, by scientists who lacked this understanding themselves.

The discussion about these cases emphasized also the importance of both instruction and students' inferences from new information. The study shows that students who fail to restructure their theory had trouble considering many variables together in their judgement, as was shown in Case Study 6 by Abear* and Basema*.

The instruction was done because I had a strong feeling about the importance of instruction in making the topic more comprehensible. The statistical analysis, regarding the initial goal of teaching students to explain everyday biological phenomena in a scientific way, shows that the instruction was effective. As later shown by analysis, this change was only on the surface level. Many students still had erroneous ideas about their propositional knowledge at least in part because of the curriculum. The curriculum is influenced by outmoded paradigms and presents old postulated biological definitions that do not match recent findings in physics and chemistry. Also, early scientific conclusions are presented without making it clear that these conclusions were erroneous. With such a curriculum, even students capable of high levels of reflective thinking would have trouble formulating accurate scientific concepts on their own. The reason is that students with reflective thinking could discover the inconsistency of the information they were asked to use in forming their theory. This was the case with students in the third and fourth groups before instruction, while, students in the first and second group acquired the same erroneous ideas identical to those who postulated them. For this reason, the instruction did not greatly change the ideas for students in the first and second groups who still thought their ideas were scientific.

Therefore, I will infer that good instruction and sound inference, should be accompanied by curriculum content which presents a coherent consistent paradigm in science. The curriculum should be guided by the philosophy of science in presenting scientific information. It is important to make it clear to the students that scientists' conclusions in the history of science were derived from their initial premises which was not enough, at that time, to lead them to the most scientifically acceptable theories now. Also, teaching biochemistry should take into consideration the students' entry level knowledge in other fields, such as chemistry and physics, before presenting new information. Understanding contemporary theory about the biochemical activity of the cell demands that students understand fundamental concepts of physics and chemistry. To assume that students are clear on these concepts, when they are not, will result in limited learning for many concepts.

Evaluation Using Metaprocedural Reorganization in Instruction

The earlier findings raise a question about metaprocedural reorganization as a method to eliminate students' misconceptions. Do these results in the dissertation mean that the method itself, if used with another topic, or by another researcher, would lead to the same result; that is, would it be successful only with select students?

Depending on a critical examination of the method implied by Piagetian theorists (Inhedler, 1974; Karmiloff-Smith 1979) and the characteristics of this topic used in the dissertation, I do not think the treatment was unsuccessful for some students because of what the theory implied. The theory implied that all the partial theories of students should be stabilized before they tried to integrate them into one powerful theory. What happened when arranging the material in the treatment is that I depended on what was written on the history of biology, to identify the entry level knowledge that allowed further integration of the theory, and used this to guide the instruction. However, the students' result first put me in a real dilemma, since I found many students' misconceptions were due to the partial theories that I did not take into account when I initially arranged the presentation. Examples are the non-conservation of matter and equating energy with matter. These misconceptions are found in the history of physics and chemistry, but not in my initial readings on the history of biology.

Reading more about developing our understanding of this topic, shows that this particular topic of biology was unique because the theory was developed by integrating all the findings of the science fields (Kuhn, 1970, P. 15). Further, Asimov (1984), Lanham (1968), Mayr (1984), emphasized that if it was not for the development in our understanding about physics and chemistry, a good understanding of this topic would not have been achieved.

This means that partial stabilization of students' theories on chemistry and physics was necessary for such treatment, but the time arranged with the school for instruction by the researcher was not sufficient for that to occur. Even more important, because of my limited knowledge in the history of biology, I was not aware of the potential complexity of students' misconceptions. For example, topics such as viewing energy as a material and vitalistic thinking were beyond my knowledge base at the time that I conducted this study.

In order for such a method to succeed, the emphasis should be on both understanding the history of science and the empirical findings of the research on students' misconceptions. Understanding the history of science would provide a conceptual frame work for organizing. It also helps to identify critical questions about phenomena to help challenge students' misconceptions.

The empirical findings on students' misconceptions should be integrated to our understanding of the history of science. The first step is designing a source of reference in the history of science that allows us to identify all the primary critical misunderstandings that led to further critical questioning and restructuring of theories in scientists. The second step is integrating the findings in the history of science to the findings in students' misconceptions to allow understanding of how such generalizations for restructuring the theory in scientists could help in understanding students' thinking. The third step is controlling other sources of confusion such as students' reading in textbooks that give students inadequate information about early definitions and conclusions. I think that with controlling such factors, applying metaprocedural reorganization methods would have a better chance to succeed with more students.

Using both history of science and empirical findings on students' misconceptions to help students understand complex science concepts would be of great value here.

The following discussion concerns the answers to dissertation questions.

Conclusions

Answering research question 1

Using metaprocedural reorganization during the treatment in a theoretical Piagetian sense, raises the first question in the dissertation. This deals with whether the path that characterized the development of our understanding about the biochemical activity of the cell during the history of science, would be similar to the path followed by students who are learning these complex concepts. Throughout history, scientists formed a stable theory (called paradigms by Kuhn) in every stage of theory development. Their knowledge about the biochemical activity of the cell was characterized by developing and integrating knowledge of many issues in photosynthesis, respiration, agriculture, and ecosystem. The scientist (i.e.; Van Helmont) who claimed that plants acquire nutrition just from water also studied the burning process and discovered carbon dioxide (Asimov, 1982). Hales examined the osmotic pressure in plants in various seasons, also measured the blood pressure of animals. He also contended that plants absorbed gases from the atmosphere (Bodenheimer, 1958). Priestly discovered that plants absorb carbon dioxide and release oxygen, and he also discovered that the opposite happened in animals (Bodenheimer, 1958). Lavoisier discovered that carbon dioxide is not for plant breathing, but builds plant tissue. He also proposed that respiration is another kind of burning, and that the function of respiration is to produce energy (Bodenheimer, 1958). Leibeg not only appreciated the importance of plants as stores of energy, but also invented calorimetry to measure the amount of energy produced by burning organic compounds, and he recognized that plants absorbed some minerals from the soil (Bodenheimer, 1958).

The study shows that, to a certain degree, these underlying issues were connected in a coherent way by students too. Students tended to have coherent theories regarding these issues. Students who claimed that the plants' body is formed from nothing but water (vitalistic thinking) were the same who claimed that plants enriched the soil when they returned to it as fertilizers. They were also the same who claimed that water produced energy that is given off in the form of water vapour by the skin.

Students who recognized that light is absorbed by the plant to afford energy for all human beings, are the same who thought that organic compounds form from only energy and decompose into only energy. They were also the same who acknowledged the importance of soil in plant growth.

Students who considered carbon dioxide as the gas used in plant breathing, were the same who did not know how it combines with water to form glucose. They also did not know this gas is released from organic compounds through respiration. On the other hand, those students who acknowledged that carbon dioxide combined with water to form glucose were the same who acknowledged that the source of carbon dioxide given off by animals during breathing is organic compounds.

In conclusion, the first question reveals that high school students develop a variety of explanations for complex scientific phenomena. In many students, these explanations are structurally coherent, given the knowledge which the students possess and, they are similar to conceptual deficiencies that parallel those explanations of early scientists.

These results showed that students at the secondary stage were consciously aware of their theory and tried to reflect on it to explain everyday life phenomena, although many explanations were erroneous. Some students still have erroneous ideas in their propositional knowledge (even after instruction). This type of knowledge, which tends to be abstract, needs a basic understanding of the fundamental principles of chemistry and physics. Although students with vitalistic concepts succeeded in making good inferences about several topics if specific information was provided, they were unable to do so when they had to connect various types of information together in reasoning. This was clear in their failure to reason the function of DNA, which requires systematic connections to many relevant subjects. This result agreed with Carey's explanation (1984) about the kind of inference that allows strong restructuring of theory. Carey said in the revolutionary type of scientific theories, the learner would need to integrate all of the relevant scientific information available, in order to form a strong coherent theory.

Answering research question 2

The second question investigated the effect that students' entry level knowledge and textbooks had on students' understanding about the biochemical activity of the cell. Theoretically, Vygotsky was concerned about how students learning of new concepts would be influenced by a) the sociocultural factors of previous formal schooling b) informal experiences outside of school and c) students' entry level knowledge.

It was evident in the history of science that the shift from the Aristotelian vitalistic approach to mechanical reductionism was accompanied by a shift of emphasis from the special autonomy of biology to considering that the physical and chemical laws that govern outside phenomena are the same which work on the body's organism too. This was a necessary step in developing our knowledge about the biochemical activity of the cell (Mazzeo, 1967). Also, the history of science shows that a fundamental understanding of chemistry (which replaced the phlogiston theory) was essential. Specifically it was important to know that carbon dioxide is a gas that combines with water to form plant substance. Also, the shift from considering heat as a substance to considering it as a type of energy, was necessary to understand the chemical reaction that occurred during photosynthesis and respiration (Lanham, 1968).

Investigating the restructuring of knowledge in students, reveals that a similar understanding of these issues was necessary before students could make the similar shift of scientists. The treatment was not effective in students who held vitalistic beliefs.

Those students employ the same naive ideas as the ones identified earlier by scientists, e.g., considering heat as substance and carbon dioxide as a gas used just for plant breathing. The developmental level of students' scientific theory determines their ability to restructure their theories. For example, one student thought water combined with carbon dioxide to form organic compounds which, in addition to energy, are responsible for plant weight. (This corresponded to Lavoisier's theory). Other students thought of energy and water as sources of weight, while carbon dioxide was considered necessary for breathing (Priestly's theory). When the researcher made it clear that light is weightless, the student that employed a conceptual structure similar to Lavoisier's restructured her theory into a scientific one, while other students who believed that carbon dioxide is used in plant breathing, did not. When those "vitalistic" students stopped thinking of light as a source of weight, they turned instead to the division of "chlorophyl cells" which was the students' literal interpretation for the textbook. They thought that body would grow by cell division, independent from the raw material absorbed from outside. This latter misconception is also found also in the history of science. The scientists who discovered cell division thought it had an independent life, disregarding nutritional input. This separate conceptualization about the work of the cells and their biochemical activity is still inherent in the textbook. This can lead students to exhibit the same thought process as the early scientists.

The controversial issues that define the philosophy of biology as either deterministic reductionism, similar to physics and chemistry, or an indeterminable natural historical one, drawn from Darwinian theory (Mayr, 1982) have an impact on vitalistic thinking among students. The conventional way of classifying topics in biology is: biochemical activity of the cell explains the function of food for energy, leaving adaptation to environmental factors. Variations of species was considered an evolutionary problem. The growth of the body through cell division was discussed in another section, without discussing the source of raw material for cell division. Thus textbooks do not clearly integrate the function of photosynthesis with DNA and cell activity. This leaves a gap in defining where the components used in cellular division came from? What is behind the variation of species? What materials form the body and how are they formed? These questions are answered by current scientists in an a unified theory that integrates all the various issues about the biochemical activity of cell. However, many of these issues were classified under other topics in biology textbook. This constitutes one of the reasons behind persistence of vitalistic thinking in students. For example, if the source of raw material for cell division was clear for students, they probably would be less likely to think that cell division would bring extra material independent from outside.

These separate conceptualizations increase the sources of confusion in students which can prevent efficient learning. Some students thought they held a sound scientific thought or idea, while in fact they held historical misconceptions they acquired unconsciously from the textbook. It also made it harder for students who held the concept of conservation of matter, to use their abstract propositional knowledge to explain everyday biological phenomena. The study reveals that those students with a good understanding of fundamental principles in chemistry before the treatment were the ones who made the most mistakes in the pretest regarding the function of photosynthesis and respiration and relating it to everyday biological phenomena. However, there was great improvement with the treatment. It is my inference that because students in the third and fourht groups had discovered the inconsistency between propositional knowledge and functional knowledge, it was difficult for them to utilize the functional knowledge given in the textbook. Salam's argument in Case Study 3 is an example of the point when she said "why would we die from less oxygen, if the body is able to generate ATP through anaerobic respiration?" and "If every cell needs oxygen, why is it the brain cells are most affected by less oxygen?"

Summary

This discussion reveals many important factors in making students comprehend scientific concepts. The first factor is to make students develop their own inferences to explain scientific information, and try to make students relate all the information together to see if it is consistent with various concepts they have in other scientific fields. The study shows that students who fail to restructure their theory had trouble considering many variables together in their judgement, thus, reemphasizing Inhedler's contention that students must integrate many variables to develop understanding of complex concepts (Carey, 1984).

Consistent presentation of information during instruction is also important. Pretest results show that students in the third and fourth groups who are capable of high levels of reflective thinking had trouble integrating scientific concepts on their own. The most difficult task they faced was to resolve the inconsistencies in all the information. However, they did show great improvement with the treatment.

The conclusions from the questions in the dissertation also show that students' entry level knowledge is important to allow further restructuring of the theory. Students who failed to restructure their theory had conceptual structures that lacked many important elements needed to comprehend the topic of study. Students who succeed in restructuring their theory had theories similar to the scientists in the 19th century in their propositional knowledge, while those who failed had theories similar to Priestly's and Van Helmont's in the 17th and 18th centuries.

This leads to the third factor of the textbook, the importance of affording consistent information and integrating it with physical and chemical principles, in addition to everyday life phenomena. I maintain that stabilizing Priestly's and Van Helmont ideas did not come by accident to some students, but from the conclusion of historical experiments and earlier definitions presented in the textbook. Some students who lack a good understanding of physics and chemistry were able to use these erroneous ideas to explain everyday biological phenomena.

In conclusion, the effect of the treatment cannot be isolated from the effect of the textbook and the ideas which students had when the instruction on the topic began. The treatment was effective with students whose entry level knowledge was of the type found in the third paradigm. That included conservation of matter. The study was not effective on students with vitalistic thinking whose entry level knowledge came from the second paradigm type. The textbook conceptualization also affects kinds of information which each group of students is able to understand, since ideas presented in the textbook often are learned but not integrated into students' thinking.

Significance of the Study

Many of the misconceptions identified in this dissertation were identified in many previous studies which emphasized the characteristics of the learner and his entry-level knowledge as a reason for unsuccessful learning. The unique thing in this dissertation is that it shows that those misconceptions tended to be coherent, in terms of individual students' knowledge and reasoning. Each student was examined longitudinally, through seven lessons conducted over a four week period, to see how each concept related to the others in the sequence, and how this could be generalized to other students. Also, discussion of related concepts during instruction, using questions which elicit both propositional knowledge and functional knowledge, allows explanation of the interconnections of all students' concepts, and recognizing of the presence or absence of either type of knowledge in these students.

Another related finding in addition to the tendency of students to have coherent conceptions in all the related issues that underlie the biochemical activity of the cell, is the ability of students to consciously explain and give rationales for their ideas. This dissertation reports six Case Studies which presents and then analyses these explanations which are examples of students who have reached the stage of developing a stable theory, as described by Piaget.

Another unique feature of the dissertation is the analysis of conceptual content of instruction according to four historical paradigms from the history of science, and analysis of students' misconceptions according to these paradigms. This process showed that students' misconceptions frequently parallel historical paradigms, which suggests that students who are learning science frequently have difficulty with some of the same conceptual problems that caused scientists difficulty in earlier generations. The study shows that while many students restructured their spontaneous naive ideas according to the functional knowledge in the textbook, they still have the naive ideas in propositional knowledge similar to the ones shown in the second paradigm. These naive ideas were derived from historical experiments and definitions included in the textbook. The study reveals the structuralist ideas (vitalism and conservation of matter) were the most important factors in determining the ability of students to restructure their theory into a scientific point of view.

Another significance of the study is that it studied a group of high school students while they were going through the process of instruction on the topic. This helped to expand our understanding of how difficult it is for teachers to "uncover" students' misconception.

Also significant was investigating students answers, using qualitative analysis through pretest, data from their dialogues in the lessons, the homework, and the posttest.

Implication

Implication for curriculum

Since the results show that students had coherent misconceptions regarding the roles of soil, photosynthesis and respiration, it would be better to present the roles of the soil and ecosystem concepts in relation to photosynthesis and respiration in the textbook instead of separately. Stressing the concepts of photosynthesis and respiration without stressing the role of soil and the mechanism of growth at the same time, leaves a gap which students fill in with misconception. When the textbook conceptualized the meaning of food to afford energy, some students filled the gap by believing that the bodies of plants come just from water, or soil, or that it makes the body itself through cell division. To enable the subject matter to flow logically in students' minds, textbook's conceptualization should integrate these contiguous parts.

Human genetics (studying the full function of DNA), could be an interrelated field that fills the gap of limited conceptualization about the biochemical activity of the cell and integrates it with various functions in the body. It is important to know that cell division and the growth of the body depend on raw material supplied from the outside.

Presenting isolated historical experiments without showing students that the conclusions were modified by later experiments, along with otherwise unintegrated curriculum does a double injustice: 1) it makes the students' vitalistic misconceptions look scientific, 2) it makes it harder for students who have conceptualized and integrated conservation of matter to follow any systematic logic of textbook conceptualization. There are two options: either remove the historical experiments altogether, or put them in context which shows students that the conclusions of these experiments were modified by later experiments. This would help students understand that science progresses through successive reexamination of significant questions asked by scientists about phenomena.

The study confirms how understanding of this topic requires an integration of relevant information from chemistry and physics. Understanding heat as a kind of energy, and not just a flow of substance, is an important factor behind the development of our understanding about the biochemical activity of the cell in the history of science. The study shows that students who fail to restructure their knowledge had naive ideas about the concept of heat, defining it as material substance. This means similar steps should be taken to help students avoid misinterpreting the metaphoric terms about energy in the textbook. One possibility is using an integrated curriculum, in which this topic would be an object of disciplinary integration, to show students how the basic principles of chemistry and physics could be used to understand and explain our bodies' biochemical process. This would be of greater value, since the researcher maintains that vitalistic thinking is not spontaneous thinking. Dole and Smith (1988), show that students in the fifth grade began to speak about cell division as a source of growth (vitalistic thinking) after their instruction in school, while they had used the terms water and sunshine before.

Implication for teachers

The findings of this dissertation gave clear evidence about the ways in which students integrate advanced scientific concepts and naive ideas to form a personalized coherent conceptualizations of a topic taught in science. These students masked their naive ideas with technical scientific terms in ways that made it difficult for the teacher to uncover these misconceptions without in-depth analysis.

This dissertation identified the basis behind such naive beliefs. Some expression used by students appeared to be scientific, but were grounded in vitalistic thinking. An example is "organic material is good fertilizer." Students told the teacher "it is good because when it decomposes, it can be used another time by the plant because it is the same material our body is composed from." This argument seems logical, although students interpreted it to mean our body is composed from different materials than the ones outside and it is just organic material that can be used for fertilizers. Identifying the metaphysical beliefs behind these terms would save time for the teacher. He or she could then go forward and explain to the students that the principles learned in physics or chemistry, such as the concept of energy, should be used in understanding this topic. Integrating the curriculum would be of great value in helping teachers overcome students' misconceptions.

Another example are the erroneous ideas that students interpreted from the historical experiments. Most students rushed to provide scientific explanation for Priestly's experiments. They correctly predicted that the exchange of gases between animals and plants would make a good ecosystem. At the same time, those students thought that carbon dioxide was used in plants' breathing instead of oxygen, which was the same erroneous conclusion that Priestly made. Accompanying historical experiments with explanations of the fallacies of the conclusions drawn from them would help to eliminate recycling historical misconceptions in students.

<u>Implications for research on teaching science</u>

There are two methods being used to treat students' misconceptions, the ones used by Piagetian theorists which depends mostly on the history of science as a metaphor to understand the nature of students' theory, and the method used by information processing theorist which depends mostly on the empirical findings of research to challenge students' misconceptions. The treatment in this dissertation depended mostly on the history of science as a metaphor. It appears that this is a powerful tool for understanding students' theories. Thus I recommend that its use in research be expanded. However, this approach is not without its problems. What has been written in the history of science is not arranged for this task. No single resource in the history of science can provide easy access to the erroneous ideas used in explaining everyday phenomena, or the naive ideas regarding the propositional abstract knowledge in the history of science. Empirical findings from misconceptions research would help us determine the nature of students' partial theories. Comparing that to the history of science could help arrange the students' partial theories according to difficulty and recognize the fundamental questions that helped integrate scientists' partial theories into powerful ones.

The findings of the dissertation shows that the method used in this kind of research requires in-depth analysis to identify all the patterns of misconception in students (those who restructured theories and those who did not). This was done to recognize the misconceptions that prevent the restructuring of students' theories which could be invaluable in teaching this topic.

In evaluating the conceptual structure of students, the study shows that statistics only measure the absence of certain predetermined types of misconceptions, and it has little use in evaluating other persistent relevant misconceptions, not yet identified, but still implied by students' answers. Only careful longitudinal analysis of the conceptual structure of the same students could reveal its presence. For example, if the researcher considers students' answers to certain questions that measure their functional knowledge as a criterion for understanding, the qualitative analysis would reveal that many students still retained more serious misconceptions in their propositional knowledge. I believe that only a longitudinal, integrative study of the same student, while comparing such restructuring by many students, would be valuable in finding common patterns in students' restructuring of their theories. This method could uncover common elements which prevent restructuring of theory. It could also be valuable in research on science teaching, since mere summative analysis does not develop an understanding about the way students interpret scientific information.

<u>Questions generated by this research</u>

The study shows that students who failed to restructure their theory came with entry level knowledge that shows a deficiency in understanding the chemical and physical principles that led to further restructuring of scientists' theory in the biochemical activity of the cell. They gave explanations that were similar to those of scientists in second Paradigm (e.g., Priestly). The only one who suceeded to restructure her misconceptions that caused by deficiency in propositional knowledge (Ohowed) entered with a conceptual structure like Lasvoisier in the Third Paradigm. This raises a fundamental question to be answered in future research which is trying to investigate the effect of integrating the questions asked by physics and chemistry regarding conservation of matter and nature of energy in teaching in this topic, and investigate the effect of this integration on students' understanding.

A second question to be answered in future research on this subject pertain the effect of having a consistent curriculum that integrates the propositional knowledge discovered in the Twentieth Century with the functional knowledge that was discovered in the earlier centuries, while showing students how the conclusions of these earlier discoveries had been modified according to the current abstract knowledge in this field. Two samples could be used. One would receive instruction with curriculum that does not mix paradigms in presenting the topic, while another would continue studying in the conventional curriculum. Quantitative and qualitative analysis could be used in this investigation.

A third question related is to investigate more deeply if vitalism and equating energy with matter are beliefs that are held spontaneously or are they caused by receiving instruction and mixed paradigm from the textbook? This question could be answered if the instruction (using the same method in the study), was directed to students who have had no previous study about photosynthesis and respiration (e.g., fifth grade students). The problem is that fifth grade students are not at a stage where they can use abstract reflection of their theory to understand the more advance abstract concepts (e.g., DNA). However, such intervention could be of great value. If successful, it would prove that systematic presentation of information plays a greater role in learning than constraints in inferential ability of students at younger stages.

This dissertation also raises interesting questions of why those students who initially came to the study with the ability to reflect abstractly on their own thinking (having a good coherent theory regarding their propositional knowledge in chemistry and physics --students in the third and fourth groups), held naive ideas in their functional knowledge before instruction? And why were those students who still had not reached the stage of reflecting abstractly on their thinking (students in the first and second groups), able to generalize their knowledge and give scientific explanation of everyday biological phenomena at least in a superficial way? Why were students in the fourth group, although identified as having a good ability to integrate their information abstractly to form a unified theory, not able to do that without instruction? And why were students in the first and second groups able to use their knowledge, formed from their inferences, from instruction and the textbook in a scientific way, while they were unable to integrate their partial theories systematically? Although I explained this phenomenon partially in this research, future work is needed to understand these events in learning more clearly.

Autobiography

Intellectual autobiography about instructional content

The instructional content I developed for this treatment, and the process I used in instruction were not acquired from one major resource. They were developed through my developing in understanding of the process of teaching science. The steps I took in developing the material would follow.

1- At the beginning of my graduate study, I had an implied knowledge from my past experience in learning and teaching science, that the history of science is important in systematically presenting knowledge to students. I had a strong feeling about the importance of integrating physics and chemical concepts with applied knowledge. The reason for this is the deficiency I experienced, when growing up, in trying to apply scientific knowledge on my own, without a curriculum to show me specifically how to do it.

2- While studying for my masters degree, I took a course on the history of science teaching. One of the approaches interested me was systemizing the teaching of science, according to the historical development of the theory (science as inquiry).

I formed a partial theory about the importance of systemizing the knowledge according to the history of science, while ignoring the fact that this positivist approach in teaching would contradict my initial enthusiasm to understand how the theory was formed from the phenomena.

3- Another partial theory about the importance of integrating applied and theoretical knowledge in a unified curriculum (which I learned about in the same course) was still separated from the earlier approach. I took an independent course to understand more about previous attempts in teaching such an approach.

This did not make much difference in the development of my theory. In the literatures, the rationale for such programs was discussed, and some ready made programs were presented, but I did not understand specifically how to make the connection between applied and theoretical knowledge. Without this connection, I was unable to generate the application of the theory on my own. The analogy was that I cannot build a house on my own from just seeing a house that is already built.

4- When I finished studying for my master degree, I became aware, on the surface, about how the approach of the positivist school (Arons, 1983), differs from the approach used by the phenomenology school (Hawkins, 1983). Although I understood the potential of the first approach (i.e.; systemizing curriculum according to logical flow) and the potential of the second approach of integrating outside phenomena into science teaching, I was unable to see how I could use one unified approach that takes into account systematizing the presentation according to logical flow, while integrating outside problems into the presentation.

5- When beginning my Ph.d. study, I took a course on quantitative cognitive research. The course revealed how students' cognitive development matched the ones observed in the history of science. In addition there was a comparison between informal learning of math in primitive cultures and its parallel to the history of science. This approach allowed me to see the connection between systematic theory development in the history of science and scientists' familiarity to outside phenomena while building scientific theory. However, an inductive approach was used to show the connection, e.g., it was claimed that more and more practice of specific tasks would generate scientific theory. It was viewed here, that the naive to expert shift happened because the experts practice the task more (e.g., Japanese theorization about experts in abacus, and information processing theorists description for experts in chess). There was no singular clue to show how people specifically shift from one paradigm to another.

6) After being confused for more than a year by this "handicapped" approach to designing my proposal, and being unaware of the presence of any science teaching approach regarding this theorization, I reached a point of abandoning designing the proposal according to such approach, and going with some easy task questions (e.g., the difference between boys and girls in learning science). I was disappointed at my inability to do what was really on my mind. At this point, I took a course on the research on science teaching. The course gave a specific examples of the stages in students' paradigms (Nussbaum and Novak, 1967). The design was familiar to the approach I had studied one year before, about assigning students' paradigms, according to the history of mathematics. I had a hint that history of science was used to predetermine students' paradigm in Nussbaum's model, and I tried to do the same when designing the developmental stage of restructuring the theory of photosynthesis.

This was a great experience, it showed me specifically that the development of theory in the history of science happened through the integration of many partial theories, not only in photosynthesis, but also in respiration, ecosystem, agriculture, nutrition, and genetics.

Also, it showed me specifically that scientists tried to find an explanation for the phenomena they see, not because they practiced more and more, but because they want to find a logical reasoning for an event that was not explained by their earlier theory.

7- When I reached this stage of having specific knowledge about scientists' work in the history of science, I became more interested in reading about Piaget's understanding of theory change. I found the approach used by Piaget and his followers better described what I understood in the history of science. I also reread the articles from the course I had taken two years before on the history of science teaching. All these articles agreed that the theories were first reached by deducing from the phenomena, not the reverse.

8- I was still confused by the large volume of historical experiments regarding the topic, and to use them all in teaching would be a waste of time. Reading Carey (1976, 1982, 1984)) allowed me to look for revolutionary theories for designing the treatment and the test questions. These articles were made available from Klopfer (1976), and her personally (1982, 1984). Although I did not study her work in any specific course, the significance of her work in science teaching was pointed out in the course I took one year before about quantitative methods in cognitive psychology. Carey suggested in her articles that the emphasis should be on restructuring students' idea about revolutionary scientific concepts, this would have great potential in learning science.

9- In all of these efforts, I was guided only by instinctive feeling about what would work in science classrooms. Until that time, I was unable to find a learning theory that could sum up all these bits I was trying to collect. In a course on cognitive psychology, I read about Inhedler's metaprocedural reorganization. In this approach, I saw a way to summarize all the things I was trying to integrate in teaching science. Vygotsky's approach helped me find a theoretical approach for intervention, since Piaget claimed that reaching the upper cognitive stage come naturally, the sociocultuaral factors were not included. With Vygotsky's approach, it became possible to use the path described by Inhedler for scientists in intervening and restructuring students' theories.

10- Although guided by all these theorizations, I was unable to find a specific solid procedure to use in my instruction. The reason is, I was unable to specifically use the scientists' work in a straight forward logical questioning, hypothesizing, and conclusion, because I lacked specific disciplinary details about the process of theory development in the history of science. A course in philosophy about the nature of science, allowed me to be specific about that.

I eventually became aware of different science teaching approaches that use the history of science (Posner, Nussbaum, Novak & Driver and Erickson), these articles come to my attention after I had formed my treatment.

<u>Research autobiography</u>

1- My first experience with applied educational research were studies that depended on statistical analysis to evaluate the difference between adults and children in perception, (e.g., that perceiving the concept of division is more difficult than the concept of multiplying -Wilkening, 1981). This research showed that perceiving the average is more difficult than perceiving distance. Two Way ANOVA, explained by graphs showed the differences between adults and children in perceiving these concepts.

2- I became interested and tried to learn more about statistical methods so I could carry on similar research. After taking many courses in statistics, I tried to apply such statistical methodology in designing my research, using statistics to arrange scientific concepts according to difficulty. Unfortunately, I neglected to note that many revolutionary scientific concepts depend on complex reasoning in which the kind of information and the entry level knowledge, not only the mental development per se, are predetermined factors of perception. I ignored the fact that average and distance concepts (and many others used in this kind of research) are "quantitative" concepts, mostly perceived intuitively. They did not depend on complex interrelationships of entry level knowledge and mental development in students. Being aware of the other contradictory partial theories through my studying of science teaching about the effect of the entry level knowledge in students' development of their theories, left me unsure of how to design my research. My design was weak and illogical. It did not make sense to me, not to mention the advisory committee.

3- I put these efforts aside to try some easy research questions, typical ones used in statistical research, like the difference between boys and girls in their ability to reason biological information via chemical and physical problems. General questions on biological, physical and chemical reasonings are easy to find in already standardized tests. This type of research requires less experience to design.

4- I quit this effort for another simple reason: When I discussed my proposal with a Jordanian student in cognitive psychology, he said "So what? What would you or your country achieve from this kind of research? Any way, do you think there would be a separate curriculum one for boys and one for girls?"

Although abandoning this line of research was not affected by being aware of inherent methodological problems in this kind of research. It came to my attention later, during a course in multivariate analysis, the fallacy of research that depends on finding statistical differences for variables between subjects without a predetermined theory. The instructor pointed out that statistics should prove the hypothesis that derived from a clear theory, formed through reasoning, not the reverse. The conventional procedure used in statistical research is to find an explanation for the correlation between given variables, without a predetermined theory of why those variables were chosen at the first place. Also, in an ethnography course, the instructor's advise was that ethnographical research should be the first step in forming the theory, and statistics could be used later in generalizing what was hypothesized through ethnographic research.

5- When I took a course on research in science teaching, Nussbaum and Novak's research model on the earth's concept (1976) was typical of the kind of research the class introduced. In this model, the concepts appeared to be arranged according to difficulty, the same as in the history of science. In addition, the questions that students were asked to answer tested their ability to apply their concepts to everyday phenomena. I assumed that by using the same model in my research design, I would solve two problems, the treatment problem of presenting the information according to its difficulty taking into account students functional information, and the methodological problem of evaluating the questions according to their difficulty. I tried to arrange the concepts of the biochemical activity of the cell according to their historical development, using the same model.

Still affected by statistical methods, I used a Split-Plot design to discover the differences between students in experimental and control groups in a pretest -treatment- posttest experimental design.

6- I became aware, later, that predetermining the score's scale for students' reasoning is not valid. I was affected by what was implied by Vygotsky's theory in my cognitive psychology course, and my readings about phenomenology and New Marxist methods of research in curriculum theory course. These approaches implied that students differ in reasoning the same kind of information, according to their genetic and past experiences, and that the evaluator himself could not predetermine these types of reasoning. Feedback from students, after instruction, would help to understand more the different types of reasoning that differ according to their backgrounds.

I abandoned my efforts of depending on statistical analysis in determining the nature of students' theories. Instead, I depended on students' reasoning in the homework, to understand the nature of their theory. I depended on statistical analysis to evaluate the success of the treatment (using a Covarience design). At that time, I considered that the students' success in making correct predictions and generalizations of their knowledge would certainly mean their successs in comprehending the scientific concepts

7- After taking a course in ethnography, I understood more about Blumer's theorization (1969) of the connection between the evolution of the theories of natural science and the method that should be adopted in social science in conducting research. I found this approach greatly resembled what Inhedler had suggested about the evolution of the theory in children-- "metaprocedural reorganization." Blumer suggested that the researcher should consider all the connections in the system, changing his primary anticipation according to empirical results and trying to understand other relationships in the system, until his anticipation agreed with the empirical results. Also at that time, I read an article by Driver and Erickson (1983), in which they suggested that research on science teaching should focus on a longitudinal study of all the students' reasoning throughout the instruction to allow understanding more about the way students construct their theories. Driver and Erickson were following Brown's suggestion (1982). On rereading Brown (1984), I found out that the suggestion was derived after considering how metaprocedural reorganization, as a method, guided research on students' learning.

Affected by my readings about Blumer and Driver and Erickson, I decided to record all the students' reasoning throughout each settings of instruction, hoping, I would understand more about the way students construct their theories.

<u>Changing the emphasis of research questions</u>

1- As discussed earlier, I was having a general idea that teaching, according to metaprocedural reorganization, would make comprehending scientific concepts easier. My theory about students' entry level knowledge depended on what I drew from its resemblance to the history of science. I thought that I could understand more from students' homework and their discussions on the lessons.

After collecting the data in November, 1986, the first thing I did was to enter students' answers in the pretest and the posttest into a Data Base program that depended on using scientists reasoning in the history of science as a criteria to determine which answer was the better. I transmitted these grades into the statistical program for covarience analysis.

There were significant statistical differences between the experimental and control groups. I felt good about the result, although there was initial uncertainty. Students correctly circled the answer of the second question on how much of the plants' weight comes from soil. They indicated they know that the plant consumed less than 1% of its weight from the ground since plant makes its body through photosynthesis. When I looked through their answers on other questions, I discovered hints that they believed that carbon dioxide is used in plant breathing, instead of oxygen. I told myself that these were was unintentional mistakes, for how could they believe that the weight of plants come from photosynthesis and yet think that carbon dioxide is used in plant breathing?

2- As I followed the experimental group members' answers throughout instruction, and the homework, I found, to my disappointment that many students were not giving scientific reasoning in their homework in the way I had anticipated. Also, during instruction, I found that many students gave a statements that revealed a misconceptions that I was not aware of during instruction. This was evident after I carefully listened to the recordings. Examining the data for all the students, however, did not enable me to see if the wrong answers were consistent, or determine if the conceptual structure for the student, taken individually, lacked or maintained the basic scientific ideas about the topic.

3- Following the recommendation of my advisor, I chose three students, specifically, the most talkative during the dialogue, to see how their ideas changed after instruction. I found to my surprise that students' misconceptions were consistent and related to each other in various concepts under study. This examination verified that I should not depend on my initial instincts that statistical analysis would determine the success of students in comprehending the issues.

4- After reaching this stage of analysis, and following further recommendation of my advisor, I compared the nature of students' understanding about each principle I addressed in the treatment in a summary table (horizontal and longitudinal comparisons). The longitudinal study compared the same students' conceptual structure in each issue that was discussed (e.g., how the conceptual structure in one issue relates to the others). The horizontal comparison included how every student's conceptual structure differed or was similar to other students, regarding each principle addressed in the lesson. To my surprise, I found that the conceptual structure of two students (Abear* and Basema*) were identical to each other, regarding most of the principles addressed through instruction, and that through instruction these two students restructured their theories similarly to those of a third student (Kholowed**). However Kholowed did not restructure her theory to the scientific one which was intended as an outcome of instruction. Her theory remained vitalistic, although her answers changed on the surface. For example, instead of saying that light is responsible of plants weight, she included the division of "chlorophyl cells" which was her own invention.

5- Although reaching this conclusion, allowed me to see coherent consistent answers in students, it was disappointing to see that the one and a half years plus that I spent planning the treatment did not result in what I had anticipated. I then investigated whether all the students in experimental group had the same conceptual structure of the topic. At this stage, I reached the level of analysis that Blumer asked for; investigating all the interrelationships in the setting until the empirical findings matched the anticipation: For example, I initially analyzed the Abear's* and Basema's* answers, two students chosen in the primary analysis. I read then Asma's*, answer to the second question in the pretest which stated that "the body of the plant does not need much from the soil, since all that it takes from the soil is the organic material." Depending on Abear's* and Basema'* previous answer, I anticipated that she would say in the fifth question that the soil would be enriched with fertilizers by planting grain, and she would say in the sixth question that water would give energy to the body. To my astonishment, I found that she did indeed responded in the same way. I also discovered two other students who have a similar conceptual structure of a third student, Kholowed in the initial analysis. In the beginning, they considered energy as a material, and that carbon dioxide was used for plant breathing.

To my relief, I found that there were four students who restructured their theories into scientific ones. However, those students did not participate as much in the class dialogue regarding generalizing the scientific concepts into everyday biological phenomena. This is the reason that they were not considered in the primary analysis. Those students in the third and fourth groups, however, gave a consistent answers indicating having correct propositional knowledge before instruction, unlike the other six in the first and second groups who only gave a superficially correct answers in relating everyday phenomena into scientific concepts while having misconceptions in their proposotional knowledge. Those four students in the third and fourth groups demonstrated correct propositional knowledge, from the beginning.
6- Reaching this level of analysis, I reorganized the literature review, and the methodology to explain these results.

One of the puzzles I wanted to solve was that if I had arranged the treatment according to the entry level knowledge that appeared in the history of science, why were there unaccounted for misconceptions in the primary treatment (e.g., considering light and energy as material substance). I thought the treatment was unsuccessful because I did not take into account contemporary misconceptions. Through my rereadings of the history of science, however, I found that these were not really contemporary misconceptions, but did indeed appear in the history of science and its understanding was a prerequisite for restructuring scientists' theories about the biochemical activity of the cell. In my initial planning for the treatment, this kind of analysis of scientists' theories was not found in the books that I had first read on the history of biology.

7- I also anticipated, after reading the students' answers, that these resemblances between students' misconceptions and the ones in the history of science was not a natural occurrence. It became evident that students had acquired the sophisticated misconceptions such as considering energy as a material and carbon dioxide as a gas used in plants' breathing, instead of oxygen from the textbook. The types words that students used, gave me the feeling that textbooks played a big role in this development. Reanalyzing the statements used in the textbook regarding its presenting for the scientific definition and the historical experiments strengthened this feeling. I found that students used textbook words as analogies to make abstract concepts real. I explained the parallel between students' misconceptions and the scientists' sophisticated ones in that the textbook's statements had incorporated historical statements used by early scientists, in which these statements were not analogies but real, but were now being used as analogies. Students who lacked sufficient propositional knowledge of chemistry and physics, as did early scientists, read these statements and explained them in the same way as early scientists.

8- It was necessary now to unify all the partial theories that were formed through empirical analysis into one powerful general theory. In all these stages of analysis, I depended on narrow empirical, evidence to explain the results. Initially, it was difficult to return to general cognitive theory to explain the results. At the start, I thought that Piaget's theory implied that students' success in making "any kind of inference" would mean their ability to comprehend scientific concepts. My earlier assumption about Piaget's theory contradicted my results. Many students were successful in making scientific inference through the lessons if the specific relevant information was given, but were still unable to comprehend scientific concepts the way they should be.

However, rereading Piaget in depth showed that his theory implied that at primary stage, students could make inferences that stabilized their theories accordingly, but they would still unable to do that for concepts that required combining many variables such as comprehending a revolutionary, complex concepts. Students often would have separate partial theories, which contradicted each other if considered together. However, the last stage included the ability to consider many alternatives in one mental space. This matched my results because analyzing the answers of students who restructured their theories showed that they had the ability to reflect simultaneously on multiple information in their analysis.

However, I had to use Vygotsky's theory to complete my analysis, since Piaget's theory does not explain why students who fail to restructure their theories had developed historical scientific misconceptions and generalizing them in a way that looked scientific. Vygostsky's theory implied that students would internalize the implied reasoning of their culture, including knowledge gained from textbook and other sources, as well as the language people used to explain scientific concepts. This explained that, without consistent resources that provide consistent paradigm in scientific functional knowledge, students who were able to see the inconsistency of non systematic resources, and who reached the Piaget's final stage, would be unable to generalize scientific propositional knowledge on their own. This agreed with Vygotsky's theory.

The process of planning the study, conducting it, and then analysing and reporting the data has had a significant effect on my understanding of the teaching-learning process among high school students and the impact of the instruction and textbook on it. It also has made me appreciate, more than ever before, the complexity of the work of a high school teacher in organizing the subject matter of science in a way that makes it possible for students to comprehend it.

BIBLIOGRAPHY

BIBLIOGRAPHY

Aiello-Nicosia, M., and Sperando-Mineo, R. (1980). "Formal Thinking, Physics Concepts and Misconceptions: An Experimental Study," Paper presented at International Conference on Education for Physics Teaching, Trieste.

Anderson, C., and Smith, E. (1983) "Children's Conception of Light and Color: Developing the Concept of Unseen Rays Paper presented at the annual meeting of the American Educational research Association.

__________. (1985) "Teaching Science" in The Educators's Handbook: A Research Perspective Virginia Koehler, editor. New York. Longman, Inc.

Asimov, I. (1982) "Asimov's Biographical Encyclopedia of Science and Technology" Doubledy & Company, Inc., Garden City, New York.

__________ (1977) "The Domocracy of Learning," In The beginning and the End Doubleday & Company, Inc. Garden City, New York.

__________ (1964) "A short History of Biology," The Natural History Press, Garden City, New York (1964).

__________ (1984) "Asimov New Guide to Science," Basic Books, Inc., publishers New York, 1984.

Atkinson, R., & Shiffren, R. (1968) "Human Memory: A Proposed system and its control process," In K. W. Spence & J.T. Spence (Eds.), Advances in the Psychology of learning and Motivation research and Theory (Vol. 2). New York: Academic press.

Bishop, B., Roth, C., & Anderson, C. (1985) "Respiration and photosynthesis," unpublished paper, Michigan State Univesity..

Blumer, H. (1969) "Methodological Principles of Empirical Science," from Herbert Blumer, Symbolic Interaction: perspective and Methods Prentice-Hall, Inc., Englewood Califs New Jersey, p. 21-47.

Bodenheimer, F. (1958) "The History of Biology An Introduction," Wm. Dawson and Sons LTD. London.

Brown, A. (1982) "Learning and Development: The Problem of Compatibility, Access and Induction," Human Development 25, 89-115.

________, John, B., Robert, F., & Joseph, A. (1983) "Learning Remembering and Understanding," Handbook of Child Psychology, New York: Wiley, p. 119-122.

Campione, J., Brown, A. (1977) "Memory and Metamemory Development in Educable Retarded Children," In R. V. Kail, Jr., & J. W. Hagen (Eds.), Perspectives on the Development of Memory and Cognition Hillsdale , N. J.: Erlbaum.

______________________, Ferrara, R., & Bryant, N. (1984) "The Zone of Proximal Development: Implications for Individual Differences and Learning." In Children's Learning in the "Zone of Proximal Development" Rogoff, B., and Wertsch, J., Jossey-Bass Inc. San Francisco.

Carey, S. (1984) "Reorganization of Knowledge in the Course of Acquisition," Unpublished Paper, Massachusetts Institute of Technology

______. (1982) "Are Children Fundamentally Different kinds of Thinkers and learners Than Adults," Unpublished Paper, Massachusetts Institute of Technology..

______. and N. Block. (1976) "Conceptual Change in Children and Scientists'" Paper presented in Piaget Society.

Case, R. (1974) "Structures and Strictures: Some Functional Limitation on the Course of Cognitive Growth," Cognitive Psychology, 6 544-573.

________, Kurland, D., & Goldberg, J. (1982) "Operational Efficiency and the Growth of Short-term Memory Span," Journal of Experimental Child Psychology, 33 (3), 386-404.

Cawthron, E., Rowell, J. (1978) "Epistemology and Science Education," Studies in Science Education 5 31-59.

Champagne, A., Gunstone, R., & Klopfer, L. "Effecting changes in cognitive structure amongst physics students," A paper presented to American Educational Research association meeting in Montreal, 1983.

_____________, A., Klopfer, L., & Gunstone, R. (1982) "Cognitive Research and the Design of Science Instruction," Educational Psychologist, 17 (1), 31-53.

Chi, M., Glaser, R., & Rees, E. (1982) "Expertise in Problem Solving," in R. Stenberg (eds.) Advances in the Psychology of Human Intelligence, Lawrence Erlbaum: Hillsdalw, NJ.

Clement, J. (1982) "Students' Preconception in Introductory Mechanics," American Journal of Physics 50 (1), 66-71.

Conant, J. (1966) "Harvard Case Histories in Experimental Science," Volume I, Harvard University Press, Cambridge Massachusetts.

Dole, J., Smith, E. (1988) "Reading science and Students' preconception," unpublished paper, Michigan State University.

Driver, R., and Erickson, G. (1983) "Theories in Action," Studies in Science Education 10 37-60.

Eagleton, T. (1983) "Phenomenology, Hermeneutics, reception Theory," Literacy Theory, p. 52-90.

Eaton J., Anderson, C., & Smith, E. (1984) "Students Misconceptions Interfere with learning: Case Studies of Fifth Grade Students," Elementary School Journal, 64 (4), 365-379.

Erickson, K., & Simon, H. (1980) "Verbal Report as Data," Psychological Review., 87, 215-225.

Fehl, N. (1965) "Science and Culture," Chung Chi Publications, Chung Chi College, The Chinese University of Hong Kong.

Flavell,J., Friedrichs, A., & Hoyt, J. (1970) "Developmental Change in Memorization Processes," Cognitive Psychology, 1 324-340.

__________, & Wellman, H. (1977) "Metamemory," in R. V. Kail, Jr., & J.W. Hagen (Eds.), Perspectives on the Development of memory and Cognition. Hillsdale, N.J.: Erlbaum.

Gardner, E. (1972) "History of Biology" Brgress Publishing Company Minneapolis, Minnesota.

Geir, R. (1984) "Understanding Scientific Reasoning," Holt, Rinehart and Winston, New York, p. 72-77.

Gelman, R. (1982) "Basic Numerical Abilities," R. J. Stenberg (Ed.), Advances in Human Intelligence Hills, dale, Nj. Erlbaum, p. 181-203.

Gilbert, J., Osborne, R., and Fensham, P. (1982) "Children Science and its Consequence for Teaching Science," Science Education 66 (4), 623-633.

____________, and Watts, D. (1983). "Concepts, Misconceptions, and Alternative Conceptions: Changing Perspective in Science Education," Studies in Science Education, 37 (3), 292-305.

Glass, G., Hopkins, K. (1984) "Statistical Methods in Education and Psychology," PRENTICE-HALL, INC. Englewood Cliffs, New Jersey, p. 494-497.

Hatano, G. (1982). "Cognitive Consequences of Practice in Culture Specific procedural Skills," The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 4 15-18.

Hawkins, D. (1983) "Nature Closely Observed," DAEDALUS 112 (Spring), 65-88.

Hewson, M., and Hewson, P. (1981) "Effect of Instruction using Students' Preconceptual Knowledge an Conceptual Change Strategies on Science learning," Paper presented to the annual meeting of NARST, April, 1981.

Hewson, P., and Hewson, M.,, (1984). 'The Role of Conceptual Conflict in Conceptual Science Conception:Toward a Theory of Conceptual Change," Science Education, 66 (2), 211-228.

Hewson,P., (1981) "A Conceptual Change Approach to Learning Science," Eur. J. Of Science Education, 3 (4), 383-396.

Inhedler et al.,1974. in "Learning Remembering and Understanding," as cited in Brown, et al., Handbook of Child Psychology, New York: Wiley (1983) 119-122.

Karmiloff-Smith, A. (1979) "Problem Solving Construction and Representation of Closed Railway Circuits," Archives of Psychology, 47 37-59.

__________________, Inhedler, B., (1975) "If You Want to Get a Theory," Cognition 3 195-212.

Kuhn, T. (1970) "The Structure of Scientific Foundation," University of Chicago.

________ (1977) "The Function of Measurement in Modern Physical Science," In The Essential Tension: Selected Studies in Scientific Tradition and change: University of Chicago press.

Keil, F. (1981) "Constraints on Knowledge and Cognitive Development," Psychological Review, 8 197-227.

Lanham, U. (1968) "Origins of Modern Biology," Colombia University Press New York and London.

Larkin, J., McDermott, J., Simon, P., and Simon, H. (1980) "Models of Competence in Solving Physical Problems," Cognitive Science, 4 371-345.

__________, Hellery, J., & Greeno, J. (1980) "Instructional Implications of Research on Problem Solving" in W. J. McKeachie (Ed.), Cognition College Teaching and Students learning. San Francisco: Jossy-Bass.

Magner, L. (1974) "A History of The life Science" Marcel Dekken Inc. New York and Basel.

Mayr, E. (1982) "The Growth of Biological Thought" Harvard University Press, p. 66.

Mazzeo, J. (1967) "The Design of Life" The Book Press Incorporated, Brattleboro, Vermont.

McClosky, M. (1983) "Naive Theories of Motion," In D. Gentner and A. Stevens (eds.), Mental Models, Erlbaum Association: Hillsdale, NJ.

________; A. Carramazza and B. Green. (1980) "curvilinear Motion in the Absence of External Force. Naive beliefs About the Motion of Objects," Science, 210 1139-1141.

Medwar, P., (1969) "Two Conceptions of Science," in the Art of the Soluble Penguin, p. 130-134.

Ministry of Education (1985) "Al-Biologia, Elmo El-Hayat," Royal Scientific Society Press. Amman, Jordan.

Minstrell, J. (1983) "Getting the Facts Strait," The Science Teacher, 52-54.

Novak, J. (1979) "The Reception Learning Paradigm," Journal of Research in Science Teaching 16 (6), 481-488.

__________ and Gowin, D., (1986) "Learning how to Learn,"

Novick, S., and Nussbaum, J. (1981) "Pupils' Understanding of the Particulate Nature of Matter: A Cross-Age Study," Science Education 65 (2), 187-196.

Nussbaum, J., and Novak, J. (1976) "Children Conceptions of the Earth as a Cosmic Body," Science Education, 63, 83-93.

_____________. (1985) "The particulate Nature of Matter in the Gaseous Phase" in Children's Idea in Science, Edited by Driver, R. and Tiberghien Open University Press, Milton Keynes, philadelphia. Ch. 7.

Piaget, J. (1972) The Child's Conception of Physical Causality, Ottawa, N.J., Littlefield, Adams and co.

_________ (1974) "Understanding Causality," New York: W. W Norton.

Posner, G., Strike, K., Hewson, P., and Gertzog, W. (1982) "Accommodation of Scientific Conception, Science Education 66 211-227.

Roth, K. (1985) "Conceptual Change Learning and Student Processing of Science Text," Dissertation for the Degree of Ph.d., Michigan State University.

Schwab, J (1964) "The Structure of the Discipline: meanings and Significances," In G.W. Ford and LiPugno (eds.), The Structure of Knowledge and the Curriculum. Chicago: Rand McNally, P. 1-30.

______________" The Structure of the Natural Science," in G.W. Ford and L. Pugno (eds.), The Structure of Knowledge and the Curriculum. Chicago: Rand McNally, P.31-49.

Seigler, R. (1983). "Information processing Approaches to Development," In W. Kessen, (Ed.), History, Theory, and Methods, Handbook of Child Psychology New York: Wiley, vol. I, p. 129-212.

Shulman, L., Tamir, P., (1973) "Research on Teaching in the Natural Science," in R. M.W Travers (Ed.), Second Handbook of Research on Teaching. Chicago: Rand McNally, p. 1098-1118.

Simon & Simon (1980) in "Learning Remembering and Understanding," as cited in Brown, et al., Handbook of Child Psychology, New York: Wiley (1983) P.119-122.

Singer, C. (1950) "A History of Biology," Henry Schuman. New York, 1950.

Smith, E., Baird-Pennoni, M., &Dubay, J. (1985) "Ecological Matter Cycling," unpublished paper, Michigan State University.

Stewart, J., Atkin, J. (1982) "Information processing Psychology: A Promising paradigm for research in Science Teaching," Journal of Research in Science Teaching, 19 (4), 321-332.

Strauss. (1981). In R. Driver & E. Erickson "Theories in Action," Studies in Science Education, 10 (1983).37-60.

Treagust, D. (1985) "Diagnosis Tests to Evaluate Students' Misconceptions in Science," a paper presented at the annual meeting of NARST. French Lick Spring, Indiana.

_________, Haslam, F. (1986) "Evaluating Secondary Students Misconception of Photosynthesis and Respiration in Plant," WAIT, Bently, Australia,.

Vygotsky, L. (1978) Mind in Society, Harvard University press Cambridge Massachusetts

Wandersee, J. (1983) "Students Misconception about Photosynthesis a Cross-Age Study," a paper presented at the International Seminar on Misconception in Science and Mathematics, Cornell University, Ithaca, New york 14853 USA.

Wellman, H. (1983) "metamemory Revisted," In M.T. H. Chi (Ed.), What is memory development the development of? A look after a decade.

Wilkening, F. (1981). "integrating Velocity, Time, and Distance information: A Development Study" Cognitive Psychology, 13 335-378.

Wiser, M., Carey, S. (1983) "When Heat and Temperature were One," In D. Genter and A. Stevens (eds.), Meta Models, Academic press: New York.

Za'rour, G. (1975). "Science misconceptions among certain groups of students in Lebanon," Journal of Research in Science Teaching, 12 (4), 385-191.

APPENDICES

APPENDICES

APPENDIX A

Test Questions Used in Qualitative Data Analysis.

In the space supplied below each question, please justify your answers.

1. Here is a list of things you might provide to a rose bush to keep it in good condition.

Mark all the correct answers, and justify.

a) light

b)water

c) fertilizers

d)soil

e)air

f)bug spray

2. Suppose that you threw an olive seed in a container of soil; after some years, the olive seed will grow up into a big tree. How much weight do you think the soil lost. (without considering water loss)? Mark the correct answer, and justify in the space supplied below.

a) about 100% b) about70% c) about 1% d) 0%

3. The amount of oxygen dissolved in a lake can be changed by the plants and animals living in it. Suppose we measured the amount of oxygen dissolved in an aquarium next to a window at these different times (note that the aquarium does not have an aerator).

a. at sunrise

b. at noon

c. at sunset

d. at midnight

a. At which time would we find the most oxygen in the water?

Why?

b. At which time would we find the least oxygen in the water? why?

4. You have a small piece of land and you want to use every bit of it. What do you think is the best thing for you to do? Mark the correct answer and justify.

a) put beans and cereals together in the same field.

b) plant the cereal in the first year and then, beans in the second year.

5. A human being needs energy to maintain biochemical activities. What is the main source of energy that a person depends on to get the energy he needs? Mark all correct answers. and justify.

a) vegetables

b) water

c) non fat milk

d) potato

6. Where in the human body does respiration take place? Mark all the correct answers and justify

a) stomach

b) muscle

c) lungs

d) skin

e) brain
1

7. Humans engage in respiration. Which other living things engage in respiration? Mark all the correct answer and justify.

a) snail b) bacteria c) rose plant d) cow e) mushroom

APPENDIX B

Homework Questions

1. The first lesson.

A small tree was planted in a meadow. After 20 years it had grown into a big tree, weighing 250 kilograms more than when it was planted.

Where did the additional 250 kilograms come from? Explain you answer as fully as you can.

The second lesson

Trees such as figs and oaks grow new leaves and then lose them each year. Together these leaves amount to a lot of material. Where does this material come from? Explain as completely as you can.

The third lesson

During a winter of heavy snow, many animals have difficulty finding food. Therefore, these animals tend to lose weight. What happens to the weight they lose? Explain as completely as you can.

fourth lesson

2. A baby chick was fed grain and water. In six weeks it had eaten about 4 pounds of grain. What do you think happened to the material in the grain the chick eat.

The fifth lesson

1. What is the difference between the burning of match wood and respiration?

2. What prevents the system invivo in balancing with the system invitro?

The sixth lesson.

1. Why does respiration process not lead to the burning of mitochanderia?

2. What is the type of energy that ATP molecule condense between its molecule and how does this happen?

The seventh lesson

You notice a person who smoke many cigarets, you try to explain to him the dangers of smoking on his health, but he answers that he knows many people who smoke many cigarets without being affected by such diseases. What would your scientific arguments for this person be?

APPENDIX C

Treatment

Key Question	Action	Rational
The First lesson		
1.What makes the earth a suitable home for living organisms	students discuss what they think makes the earth a suitable environment for living organisms	Students know that, in general, light, fertilizers soil, air, water and moderate temperature are essential for life
2.How much do we need from each of these components of life	a. students pay attention to many phenomena in which plants grow over thin layer of soil (read Van Helmont's experiment in the book), they discuss the major source of plant growth	students know that most of a plants' weight is due to water
b. Do we need anything beside water from the atmosphere	b. students pay attention to many phenomena in which plants do not grow without a green component at the stem or on the leaf (verbal demonstration' of Hale's experiment about increasing the absorbing of water in the season of plant growing). They will discuss if they still think plants grow from the ground only	students know that carbon dioxide from the air is absorbed by the plant through the green component,in which it, beside water from the ground, are responsible of plant growth
c. What type of air do plants absorb from the atmosphere	c. students pay attention that human beings inhale and exhale two different types of air; they will discuss which gas they think that plants absorb (read Priestly's experiment from the book). They also explain the constant percentage of gases in the atmosphere	students make a connection, between animals and plants' activities and relate them to the ecosystem; They know that carbon dioxide is the gas which is absorbed by plants
d. Why in the dark,	d. Students discuss	students know

Key Questions	Actions	Rational
don't we find the balance in exchanging gases between plants and animals hold true	the phenomena in which plant does not grow even in the presence of green leaf, water, and air, without a light. They discuss why we can't sleep in a closed room full of plants in the dark while we don't worry about that in the light (compared to Priestley's experiment using verbal discussion about Ingenousz exper, beside read the exper (page 85) in the book about exchange of gases in the plant	that absorbing carbon dioxide would not happen without the presence of light, also plants make breathing in the same way as animals but to a less extent
The Second lesson		
3. What is this component that plant form from this process	Students observe that if we burn any type of plant or animal tissue, it is always carbon dioxide and water that are the by products of this burning. Students observe that most summer crops that appear over the ground have a sugar taste, while those which is stored at the root has a starch component. Verbal demonstration of Kirchholf's experiment in which he proves that various forms of carbohydrates appear in a glucose form by adding acid to it. Also discussion of pages 16,17 in the book which show the structure of sugars and carbohydrates, also read the upper part of page 64 which shows the equation of the reaction between carbon dioxide and water (I will not go into detail of Kelvin Cycles or dark and light reactions as the book has done)	students could appreciate that glucose is one of the first components that form during chlorophyl synthesis, this component could restructure into various forms by plant, but the animals have the ability to return it back into mono saccharides form by enzymes or acids in their digestive system
The third lesson		
4. What is the function of these hydrocarbon components for living organisms	Students connected what they studied first, that plants absorb carbon dioxide and water by the presence of light to form the food for organisms. By burning any type of plants or animal tissue, Carbon dioxide and	students reach a conclusion that respiration is some type of burning that happens through a slow process. Students

Key Questions	Actions	Rational
	water would be released from this burning. Also through respiration, we consume oxygen and release carbon dioxide and water just as in burning. Also human being breath more when they make more muscular work and feel warmer. Students read the bottom of page 83 until half of page 85 which compare respiration by burning and the difference between them. Also page 72-74 which discuss the same thing and discuss the chemical energy that organic compound hold and relate it to the original source (the sun) and how this energy is released back through respiration.	comprehend the rule of conserving energy, that organisms consume energy through respiration, this energy comes from food, and the food takes this energy originally from the sun.
The fourth lesson		
5. Do organisms need anything else besides the hydrocarbon component, and what function does it serve.	Students discuss the phenomena in which different kinds of crops need different kinds of lands. If we continue to plant the same type of crop year after year without adding fertilizers to it, the soil will stop giving good yields of crops as it used to. Also, human beings waste daily products of urea. This urea appear as a result of metabolism of protein Also some animals eat other animals to take their daily supply of protein Verbal demonstration of Gilbert and Lawes exper who found that different types of protein food yield different quantities of urea. The food that brings the most of urea should not be depended on as a food (such kind is not used to build the tissue in the body. It's used just in respiration) People will die if they depend on it. Students read page 78-82 which speaks about the different amounts of energy in different kinds of foods. Also read page 18-20,22 which speaks about the structure of protein and nucleotides.	Students know that food constitute of more than hydro carbon elements Plants absorb minerals from soil besides water and carbon dioxide, and that these new component do not serve as just a mere source of energy only, but in building the body of the animal itself. In general, any food that contains a hydrocarbon bond could be used any time for an energy supply
The fifth lesson		
6. After eating the food, where does the	Students discuss several natural phenomena in which we observe that	Students know that respira-

Key Questions	Actions	Rational
food go inorder to be burned, and whether the food goes directly from the digestive system into a burning process without control, or this happens that according to animal needs	the temperature is constant in all parts of the body, and that cutting the supply of oxygen from any part of it will lead to destroy this part and the part of blood has difficulty to reach is cooler than other parts of the body. Students pay their attention also to hospitals use glucose as food injected into the blood itself for patients who can't depend on their own system for metabolizing food to form this essential component. Also that we feel more hungry after exercise or in very cold or hot whether.	tion happens in every cell Students know that various kinds of food appear in glucose form in order to enter the respiration reaction
	Besides discussions of various . phenomena in food synthesis like dough, pickles, yoghurts is due to the effects of microorganisms which depend on carbohydrates and sugars as source of energy. Verbal demonstration of Bernard's experiment in which he found that whatever the animal eats protein or carbohydrate, a glucose is found in his blood. students read upper part of page 75, page 77 which speak about the control of using energy according to body's needs. Also students read bottom of page 99, page 101-102 which speak about fermentation and anaerobic reaction.	Students know that respiration process doesn't happen at one step just as in burning, but in several steps. Some micro-organisms are satisfied with the energy that comes from a mini -step due to its small body
The sixth lesson		
The question is What makes it possible that fermentation by product would happen only by living organisms; besides it is so difficult to imitate the reaction outside the body. Also how could it be that these reactions continue to happen automatically inside the body without releasing more energy than the body needs.	Students integrate their knowledge in chemistry about a catalyst which allows the reaction to go at a low temperature. They compare this to the results of Buchner's experiment in which it was discovered that a sugar solution that contains a dead yeast on it would allow the fermentation process to happen outside the body (the book does not say that the yeast was dead so the heart of the issue is lost). Also a verbal demonstration for the same experiment, when it was discovered that a continuing supplying of phosphate is essential for the process to continue out side the living organism. Also students observe that we don't have to have a daily food containing phos-	Students know that enzymes make the same function as a catalyst inside the body, but in a much more efficient way, Also students know that reactions go inside the body in a cyclic process which allows the same

Key Questions	Actions	Rational
	phor to continue living, only occasionally, like vitamins. Students read page 86, 87-90 and page 96,97 which speak about the importance of enzymes to lower the activation energy for the reaction and it also discusses that ATP can hold the energy and then release it back to appear as ADP in cyclic form. Also students read page 23 which speaks about the structure of energy carriers (ATP),	component to be used again. This is why we don't consume so many minerals. Also, the efficient way in which ADP is working to hold the extra energy.
The seventh lesson If enzymes control all the reactions inside the body, how could we explain these differences in the the type of food eaten by living organisms, although all of them go into the same procedure of respiration or part of it.	Verbal demonstration of Tatums experiment, in which he exposes pink bread mold to X rays and then follows the behaviour of the second generation. He found that molds stop being independent as before in using the inorganic medium to synthesize all the protein it needs. Also students discuss causes of diseases in general and try to explain it in the light of the new information they studied. Students read page 110 until the top of page 112 which discusses the synthesis of the protein of enzymes according to the codes on the DNA.	Students reach a conclusion that if the reactions inside the body happened by the enzymes and if organisms varied in making the reactions that produce a given component that is essential for the vital processes, then this deficiency would be due to a lack of enzymes, and the producing of enzymes itself is determined by the codes on the genes, and that diseases could be contributed to genetic factors, or to environmental factors as when the component that is essential to synthesize the enzyme is not found (malnutrition), or to strange organisms which enter the body and direct the enzyme's activity to its own purpose.

APPENDIX D

Pretest and Posttest Questions Used for Statistical Analysis

Students responses to the pretest and posttest were categorized according to a set of categories developed prior to detailed qualitative data analysis.

Categories

In the space provided below each question, please justify your answers.

1. Here is a list of things you might provide to a rose bush so as to keep it in good condition.

Mark all the correct answers, and justify.

a) light

b) water

c) fertilizers

d) soil

e) air

f)bug spray

Categories for the answers (arrange according to the most correct answer).

1-**ALL, students who mentioned that all the factors are important except the bug spray for the healthy condition for plant.**

2- **N S, students who recognized the importance of all the factors except soil (the first half of 19th century theory).**

3- CO **RES students** who mentioned that carbon dioxide is used in respiration.

4- RES O, students who recognized that plant need oxygen for respiration, without recognition the importance of carbon dioxide.

5- N A, who recognized the importance of light beside water and soil without including air (the most primitive theory).

6-N S,R, students who didn't recognize the importance of soil, they included air for respiration only.

The common thing between all the answers is that all of them include light for photosynthesis beside the water.

Selection: QUESTION equals 1 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	1	1	ALL	5
CONTROL	EMAN	1	1	ALL	5
CONTROL	FADWA	1	1	ALL	5
CONTROL	HANAN	1	1	ALL	5
CONTROL	KAREYMA	1	1	ALL	5
CONTROL	SAMEYRA	1	1	ALL	5
CONTROL	TAGHREYD	1	1	ALL	5
CONTROL	AMAL	1	1	CO RES	3
CONTROL	ROWLA	1	1	N A	1
CONTROL	WEJDAN	1	1	RES O	3
EXPER	ASMA	1	1	CO RES	3
EXPER	OHOWD	1	1	ALL	5
EXPER	SALAM	1	1	ALL	5
EXPER	SAWSAN	1	1	ALL	5
EXPER	BASEMA	1	1	N A	1
EXPER	FATMA	1	1	ALL	5
EXPER	GHAYDA	1	1	N A	1
EXPER	ABEAR	1	1	CO RES	3
EXPER	SUMAYYA	1	1	N S,R	2
EXPER	KHOLOWD	1	1	All	5

Selection: QUESTION equals 2 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	2	1	ALL	5
CONTROL	SAMEYRA	2	1	ALL	5
CONTROL	AMENA	2	1	NS	4
CONTROL	EMAN	2	1	NS	4
CONTROL	FADWA	2	1	NS	4
CONTROL	HANAN	2	1	NS	4
CONTROL	ROWLA	2	1	NS	4
CONTROL	TAGHREYD	2	1	NS	4
CONTROL	KAREYMA	2	1	NS,RN	4
CONTROL	WEJDAN	2	1	RES,O	3
EXPER	ABEAR	2	1	CO RES	3
EXPER	ASMA	2	1	ALL	5
EXPER	FATMA	2	1	ALL	5
EXPER	GHAYDA	2	1	ALL	5
EXPER	KHOLOWD	2	1	ALL	5
EXPER	OHOWD	2	1	ALL	5

EXPER	SALAM	2	1	ALL	5
EXPER	SAWSAN	2	1	ALL	5
EXPER	SUMAYYA	2	1	ALL	5
EXPER	BASEMA	2	1	NS,R	2

2. Suppose that you threw an olive seed in a container of soil, after some years, the olive seed will grow up into a big tree. How much do you think the soil had lost from its weight (without considering water loss from the soil)? Mark the correct answer, and justify in the space provided below.

a) about 100% b) about70% c) about 1% d) 0%

Categories for the answers.

1-1% st, those who recognized the importance of soil, also they stated that photosynthesis is the major factor behind building the plant's body (beside the water).

2- 0 st, those who recognized that photosynthesis and water are the major factors behind building the plant's body, but they did not recognize the importance of soil (beginning of 18th century theory).

3- 1%, those who recognized the importance of water and soil without recognizing the importance of photosynthesis. They stated that plants' body came from water only.

4- 0, those who recognized the importance of water only (17th century theory).

5-30%,70%,those who thought that plant build its tissue from soil component.

Selection: QUESTION equals 2 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	1	2	1%	3
CONTROL	AMENA	1	2	1%	3
CONTROL	FADWA	1	2	1%	3
CONTROL	EMAN	1	2	70%	0
CONTROL	HANAN	1	2	30%	0
CONTROL	KAREYMA	1	2	30%	0
CONTROL	ROWLA	1	2	30%	0
CONTROL	SAMEYRA	1	2	1%ST	5
CONTROL	TAGHREYD	1	2	1%	3
CONTROL	WEJDAN	1	2	0	2
EXPER	ABEAR	1	2	1%	3
EXPER	ASMA	1	2	1%	3
EXPER	BASEMA	1	2	1%	3
EXPER	GHAYDA	1	2	1%	3

EXPER	KHOLOWD	1	2	1%	3
EXPER	FATMA	1	2	0	2
EXPER	OHOWD	1	2	0ST	4
EXPER	SAWSAN	1	2	0ST	4
EXPER	SUMAYYA	1	2	0	2
EXPER	SALAM	1	2	30%	0

Selection QUESTION equals 2 and TEST NO equals 2

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	2	2	0	2
CONTROL	AMENA	2	2	0	2
CONTROL	EMAN	2	2	0	2
CONTROL	FADWA	2	2	0	2
CONTROL	HANAN	2	2	0	2
CONTROL	KAREYMA	2	2	0	2
CONTROL	TAGHREYD	2	2	0	2
CONTROL	SAMEYRA	2	2	1%	3
CONTROL	ROWLA	2	2	30%	0
CONTROL	WEJDAN	2	2	30%	0
EXPER	ASMA	2	2	1%	3
EXPER	BASEMA	2	2	1%	3
EXPER	FATMA	2	2	1%	3
EXPER	KHOLOWD	2	2	1%	3
EXPER	SAWSAN	2	2	1%	3
EXPER	ABEAR	2	2	1%ST	5
EXPER	GHAYDA	2	2	1%ST	5
EXPER	OHOWD	2	2	1%ST	5
EXPER	SALAM	2	2	1%ST	5
EXPER	SUMAYYA	2	2	1%ST	5

3. The amount of oxygen dissolved in a lake can be changed by the plants and animals living in it. Suppose we measured the amount of oxygen dissolved in an aquarium next to a window at these different times.(note that aquarium does not have aerator)

a. at sunrise

b. at noon

c. at sunset

d. at midnight

a. At which time would we find the most oxygen in the water?

Why?

b. At which time would we find the least oxygen in the water?

why?

Categories for the answers.

1-HE,LN, Those who stated that the biggest accumulation of oxygen would be in the evening due to the photosynthesis..

2- HL,LN, those who just recognized that there will be more oxygen in the day time due to the photosynthesis.

3-RC, those stated that oxygen would be released during the day time because of plants' breathing of carbon dioxide

4-HL,LN,T, those who thought that the percentage of oxygen in atmosphere would be bigger in the presence of light because the degree of temperature would be higher.

5--HN,LL,P, those who thought that the percentage of oxygen in atmosphere would be most bigger at dawn and night because of the pollution in the day time.

6- I get 1 point lower to those who stated one of the above reasons beside the sleeping (SL is the code for that).

7- HD,LN, those who thought that oxygen will be renewed in the day time (they did not give reason). They also thought that the amount of oxygen would be lowest in the night due to it's consuming in respiration (they did not know that plants respire always, in the night and day time).

Selection: QUESTION equals 3 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	1	3	CO,SL	2
CONTROL	TAGHREYD	1	3	HE,LN	5
CONTROL	AMENA	1	3	RC	3
CONTROL	WEJDAN	1	3	HE,LN	5
CONTROL	EMAN	1	3	HL,LN	4
CONTROL	FADWA	1	3	HL,LN	4
CONTROL	HANAN	1	3	HL,LN	4
CONTROL	KAREYMA	1	3	HL,LN,T	0
CONTROL	ROWLA	1	3	HL,LN	4
CONTROL	SAMEYRA	1	3	HL,LN	4
EXPER	GHAYDA	1	3	HL,LN	4
EXPER	SALAM	1	3	HL,LN	4
EXPER	SAWSAN	1	3	HL,LN	4
EXPER	SUMAYYA	1	3	HL,LN	4
EXPER	ABEAR	1	3	Hl,LN,SL	2
EXPER	KHOLOWD	1	3	HL,LN,T	0
EXPER	BASEMA	1	3	HL.LN	4
EXPER	FATMA	1	3	HN,LL,P	0
EXPER	ASMA	1	3	HN,LL,PL	0
EXPER	OHOWD	1	3	HD,LN,	0

Selection QUESTION equals 3 and TEST NO equals 2

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	EMAN	2	3	HE,LN	5
CONTROL	WEJDAN	2	3	HE,LN	5
CONTROL	AMAL	2	3	HL,LN	4
CONTROL	AMENA	2	3	HL,LN	4
CONTROL	FADWA	2	3	HL,LN	4
CONTROL	ROWLA	2	3	HL,LN	4
CONTROL	TAGHREYD	2	3	HL,LN	4
CONTROL	SAMEYRA	2	3	HL,LN	4
CONTROL	HANAN	2	3	HL,LN,T	0
CONTROL	KAREYMA	2	3	R MISC	2
EXPER	ABEAR	2	3	HL,LN	4
EXPER	ASMA	2	3	HL,LN	4
EXPER	BASEMA	2	3	HL,LN	4
EXPER	GHAYDA	2	3	HL,LN	4
EXPER	KHOLOWD	2	3	HL,LN	4
EXPER	OHOWD	2	3	HL,LN	4
EXPER	SALAM	2	3	HL,LN	4
EXPER	SAWSAN	2	3	HL,LN	5
EXPER	SUMAYYA	2	3	HL,LN	4
EXPER	FATMA	2	3	R MISC	2

4.Where do you expect to find the taste of the fig to be sweetest? mark the correct answer and justify.

a) The fig that you get from high branch.

b) The fig that you get from low branch.

c) The place that we get the fig from had no effect on it's taste

Categories for the answers.

1- PH, those who stated that the figs on the top will be more sweet since they could expose to more light that is necessary to synthesize the glucose.

2- H,R or L,R, those who said that the figs on the high or the low branches would be sweater according to the percentage of getting light, but those who choose the low branch for the same reason said that so much sun will destroy the fig (they did not mention clearly what the light has to do with photosynthesis).

3-IN,G ,those who stated that the place of the fig has nothing to do with it's sweetness. They stated that this would depend upon the genetic factor (IN,G)

4- IN,SOIL, those who said that the place of the fig has nothing to do with it's sweetness; the type of soil is the major factor in that (t h e y have a misconception that the soil is the place where plant get its food).

5- L,DEW, those who thought that the lower branches will be sweetest because the presence of more dew there.

6- L,SOIL, those who thought that the lower branches will be sweater because of being closer to the soil (have a misconception also that the soil is the place that plant get its food from)

7- IND, those who said that the sweetness of the fig has nothing to do with the place without mentioning the reasons.

Selection: QUESTION equals 4 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	1	4	H,R	2
CONTROL	EMAN	1	4	H,R	2
CONTROL	AMAL	1	4	IN,G	0
CONTROL	KAREYMA	1	4	PH?	5
CONTROL	ROWLA	1	4	IN,G	0
CONTROL	WEJDAN	1	4	L,SOIL	0
CONTROL	FADWA	1	4	PH	5
CONTROL	HANAN	1	4	PH	5
CONTROL	TAGHREYD	1	4	PH	5
CONTROL	SAMEYRA	1	4	IN,SOIL	0
EXPER	ASMA	1	4	L,DEW	0
EXPER	GHAYDA	1	4	L,R	2
EXPER	OHOWD	1	4	H,R	2
EXPER	KHOLOWD	1	4	H,R	2
EXPER	SAWSAN	1	4	H,R?	2
EXPER	ABEAR	1	4	IN	0
EXPER	SUMAYYA	1	4	IN	0
EXPER	BASEMA	1	4	IN,G	0
EXPER	FATMA	1	4	PH	5
EXPER	SALAM	1	4	PH?	5

Selection QUESTION 4 and TEST NO equals 2

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	EMAN	2	4	DEW,H	0
CONTROL	WEJDAN	2	4	IN	0
CONTROL	AMAL	2	4	G,IN	0
CONTROL	AMENA	2	4	PH	5
CONTROL	HANAN	2	4	PH	5
CONTROL	TAGHREYD	2	4	PH	5
CONTROL	KAREYMA	2	4	PH,IN	4
CONTROL	FADWA	2	4	R,H	2
CONTROL	ROWLA	2	4	R,H	2
CONTROL	SAMEYRA	2	4	R,H	2
EXPER	ABEAR	2	4	1N	0
EXPER	SAWSAN	2	4	IN	0

EXPER	SUMAYYA	2	4	IN	0
EXPER	FATMA	2	4	PH	5
EXPER	SALAM	2	4	PH	5
EXPER	GHAYDA	2	4	PH,IN	5
EXPER	ASMA	2	4	IN,Gl	3
EXPER	BASEMA	2	4	R,H	2
EXPER	KHOLOWD	2	4	R,H	2
EXPER	OHOWD	2	4	R,H	2

5. You have a small piece of land and you want to use every bit of ~it. What do you think is the best thing for you to do? Mark the correct answer and justify.

a) put beans and cereals together in the same field.

b) plant the cereal in the first year and then, beans in the second year.

Categories for the answers.

1- TOG, those who stated that planting different kinds of plants together is better if the two types of crops need different kinds of minerals.

2- MIN,COM, those who recognized that different kinds of crops that need different types of minerals.

3- MIN,INC, those who recognized that the plant consumes mineral from the soil but they didn't recognize that each kind of crop differ in the quantity and quality of mineral they need from each other.

4-MIN,IN, those who thought that the amount of mineral in the ground would be increased in the second year after planting the cereal.

5- SEC,NS, those who mentioned that planting crops in the second year is better because of opening the soil by the root of the plant.

Selection: QUESTION equals 5 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
EXPER	GHAYDA	1	5	MIN COM	4
CONTROL	EMAN	1	5	MIN,COM	4
CONTROL	HANAN	1	5	MIN,COM	4
CONTROL	SAMEYRA	1	5	MIN,COM	4
CONTROL	TAGHREYD	1	5	MIN,COM	4
CONTROL	FADWA	1	5	MIN,IN	0
CONTROL	ROWLA	1	5	MIN,INC	0
CONTROL	WEJDAN	1	5	SEC,NS	0
CONTROL	AMENA	1	5	TOG	5
CONTROL	KAREYMA	1	5	TOG	5
CONTROL	AMAL	1	5	TOG,NST	0

EXPER	ABEAR	1	5	MIN,IN	0
EXPER	KHOLOWD	1	5	MIN,COM	4
EXPER	ASMA	1	5	MIN,IN	0
EXPER	BASEMA	1	5	MIN,IN	0
EXPER	OHOWD	1	5	MIN,INC	2
EXPER	SALAM	1	5	MIN,INC	2
EXPER	SUMAYYA	1	5	MIN,INC	0
EXPER	FATMA	1	5	SEC,NS	0
EXPER	SAWSAN	1	5	SEC,NS	0

Selection: TEST NO equals 2 and QUESTION equals 5

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	2	5	SEC,NS	0
CONTROL	WEJDAN	2	5	TOG,NS	0
CONTROL	KAREYMA	2	5	TOG,NSOIL	0
CONTROL	EMAN	2	5	MIN,INC	2
CONTROL	FADWA	2	5	MIN,INC	2
CONTROL	HANAN	2	5	MIN,INC	2
CONTROL	ROWLA	2	5	MIN,INC	2
CONTROL	SAMEYRA	2	5	MIN,INC	2
CONTROL	AMENA	2	5	MIN,COM	4
CONTROL	TAGHREYD	2	5	MIN,COM	4
EXPER	ABEAR	2	5	MIN,IN	0
EXPER	ASMA	2	5	MIN,IN	0
EXPER	FATMA	2	5	SEC,NS	0
EXPER	GHAYDA	2	5	MIN,COM	4
EXPER	BASEMA	2	5	TOG	5
EXPER	KHOLOWD	2	5	TOG	5
EXPER	OHOWD	2	5	TOG	5
EXPER	SALAM	2	5	TOG	5
EXPER	SAWSAN	2	5	TOG	5
EXPER	SUMAYYA	2	5	TOG	5

6. A human being needs energy to maintain the biochemical activities. What is the main source of energy that a person depends on to get the energy he needs? Mark all correct answers and justify.

a) vegetables

b) water

c) non fat milk

d) potato

Categories for the answers.

1- POT, those who stated that potato is the major source off energy.

2- WAT,EN RS, those who thought that water gave energy during respiration.

3- Pot,WAT,ALL, those who thought that potato and water gave energy, or who mentioned all the sources as sources of energy.

Selection: QUESTION equals 6 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	1	6	POT	5
CONTROL	AMENA	1	6	POT	5
CONTROL	EMAN	1	6	POT	5
CONTROL	FADWA	1	6	POT	5
CONTROL	HANAN	1	6	POT	5
CONTROL	KAREYMA	1	6	POT	5
CONTROL	ROWLA	1	6	POT	5
CONTROL	SAMEYRA	1	6	POT	5
CONTROL	WEJDAN	1	6	POT	5
CONTROL	TAGHREYD	1	6	WAT,EN RS	0
EXPER	FATMA	1	6	POT	5
EXPER	GHAYDA	1	6	POT	5
EXPER	KHOLOWD	1	6	POT	5
EXPER	OHOWD	1	6	POT	5
EXPER	SALAM	1	6	POT	5
EXPER	SAWSAN	1	6	POT	5
EXPER	SUMAYYA	1	6	POT	5
EXPER	BASEMA	1	6	POT,WAT,ALL	0
EXPER	ABEAR	1	6	WAT,EN RS	0
EXPER	ASMA	1	6	WAT,EN RS	0

Selection: QUESTION equals 6 and TEST NO equals 2

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	2	6	POT	5
CONTROL	AMENA	2	6	POT	5
CONTROL	EMAN	2	6	POT	5
CONTROL	FADWA	2	6	POT	5
CONTROL	HANAN	2	6	POT	5
CONTROL	KAREYMA	2	6	POT	5
CONTROL	ROWLA	2	6	POT	5
CONTROL	SAMEYRA	2	6	POT	5
CONTROL	TAGHREYD	2	6	POT	5
CONTROL	WEJDAN	2	6	POT	5
EXPER	ABEAR	2	6	POT	5
EXPER	ASMA	2	6	POT	5
EXPER	BASEMA	2	6	POT	5
EXPER	FATMA	2	6	POT	5
EXPER	GHAYDA	2	6	POT	5
EXPER	KHOLOWD	2	6	POT	5
EXPER	OHOWD	2	6	POT	5
EXPER	SALAM	2	6	POT	5
EXPER	SAWSAN	2	6	POT	5
EXPER	SUMAYYA	2	6	POT	5

7. Where in the human body does respiration take place? Mark all the correct answers and justify

a) stomach

b) muscle

c) lungs

d) skin

e) brain

Categories for the answers.

1- ALL , those who mentioned that respiration could happen in every place.

2- BR,LN,MS, those who stated that respiration could happen in the brain, muscle and lung (memorizing bits of information, without a common theory).

3- LN,SK, those who stated that respiration happened at the lung and the skin.

4-LN,ST, those who stated that respiration could happen at the stomach where food first come in, and at the lung.

5-LN,those who stated that respiration happened at lung only (this type of misconception is similar to the theory held by scientists until the middle of 19th century.

Selection: TEST NO equals 1 and QUESTION equals 7

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	1	7	LN	0
CONTROL	HANAN	1	7	LN	0
CONTROL	KAREYMA	1	7	LN	0
CONTROL	SAMEYRA	1	7	LN	0
CONTROL	AMAL	1	7	LN,SK	0
CONTROL	FADWA	1	7	LN,SK	0
CONTROL	ROWLA	1	7	LN,ST	0
CONTROL	TAGHREYD	1	7	LN,ST	0
CONTROL	WEJDAN	1	7	LN,ST	0
CONTROL	EMAN	1	7	BR,LN,MS	2
EXPER	GHAYDA	1	7	LN	0
EXPER	KHOLOWD	1	7	LN	0
EXPER	SAWSAN	1	7	LN	0
EXPER	SUMAYYA	1	7	LN	0
EXPER	ABEAR	1	7	LN,SK	0
EXPER	ASMA	1	7	LN,SK	0

EXPER	BASEMA	1	7	LN,SK	0
EXPER	FATMA	1	7	LN,SK	0
EXPER	SALAM	1	7	LN,SK	0
EXPER	OHOWD	1	7	ALL	5

Selection: TEST NO equals 2 and QUESTION equals 7

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	2	7	LN	0
CONTROL	HANAN	2	7	LN	0
CONTROL	SAMEYRA	2	7	LN	0
CONTROL	WEJDAN	2	7	LN	0
CONTROL	TAGHREYD	2	7	LN,SK	0
CONTROL	ROWLA	2	7	BR	2
CONTROL	AMAL	2	7	BR,LN	2
CONTROL	EMAN	2	7	BR,LN	2
CONTROL	KAREYMA	2	7	BR,LN	2
CONTROL	FADWA	2	7	BR,LN,SK	2
EXPER	SUMAYYA	2	7	LN	0
EXPER	OHOWD	2	7	BR,CON	4
EXPER	ABEAR	2	7	ALL	5
EXPER	ASMA	2	7	ALL	5
EXPER	BASEMA	2	7	ALL	5
EXPER	FATMA	2	7	ALL	5
EXPER	GHAYDA	2	7	ALL	5
EXPER	KHOLOWD	2	7	ALL	5
EXPER	SALAM	2	7	ALL	5
EXPER	SAWSAN	2	7	ALL	5

8. Humans engage in respiration. Which other living things engage in respiration? Mark all the correct answer and justify.

a) snail b) bacteria c) rose plant d) cow e) mushroom

Categories for the answers.

1- ALL, those who stated that all organisms engage in respiration.

2- ALL EX MS, those who circled all the categories except the mushroom.

3- CW,TR,BC, those who stated that cow beside the plant and bacteria in Anaerobic respiration engage in respiration (they memorized bit of information without a common theory).

4-BC,MS those who circled bacteria and mushroom only saying that they engaged in anaerobic respiration (this response could be due to misunderstanding for the question).

5-CW,TR, those who circled cow and tree only as the organisms who engaged in respiration.

6-CW, those who stated that only cow engaged in respiration.

Selection: QUESTION equals 8

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	1	8	ALL	5
CONTROL	AMENA	1	8	CW,TR	2
CONTROL	EMAN	1	8	CW	0
CONTROL	FADWA	1	8	CW,TR	2
CONTROL	HANAN	1	8	CW,TR	2
CONTROL	KAREYMA	1	8	CW,TR	2
CONTROL	ROWLA	1	8	BC,MS	2
CONTROL	SAMEYRA	1	8	ALL	5
CONTROL	TAGHREYD	1	8	ALL	5
CONTROL	WEJDAN	1	8	CW,TR,BC	3
EXPER	ABEAR	1	8	CW,TR,BC	3
EXPER	ASMA	1	8	ALL	5
EXPER	BASEMA	1	8	ALL	5
EXPER	FATMA	1	8	BC,MS	2
EXPER	GHAYDA	1	8	ALL	5
EXPER	KHOLOWD	1	8	ALL	5
EXPER	OHOWD	1	8	ALL	5
EXPER	SALAM	1	8	ALL EX MS	4
EXPER	SAWSAN	1	8	CW,TR,BC	3
EXPER	SUMAYYA	1	8	ALL	5

Selection: TEST NO equals 2 and QUESTION equals 8

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	ROWLA	2	8	CW,MS	2
CONTROL	EMAN	2	8	CW,TR	2
CONTROL	FADWA	2	8	CW,TR	2
CONTROL	HANAN	2	8	CW,TR	2
CONTROL	KAREYMA	2	8	CR,TR,BC	3
CONTROL	AMENA	2	8	CW,TR,BC	3
CONTROL	WEJDAN	2	8	CW,TR,MS	3
CONTROL	AMAL	2	8	ALL	5
CONTROL	SAMEYRA	2	8	ALL	5
CONTROL	TAGHREYD	2	8	ALL	5
EXPER	ABEAR	2	8	ALL	5
EXPER	ASMA	2	8	ALL	5
EXPER	BASEMA	2	8	ALL	5
EXPER	FATMA	2	8	ALL	5
EXPER	GHAYDA	2	8	ALL	5
EXPER	KHOLOWD	2	8	ALL	5
EXPER	OHOWD	2	8	ALL	5
EXPER	SALAM	2	8	ALL	5
EXPER	SAWSAN	2	8	ALL	5
EXPER	SUMAYYA	2	8	ALL	5

9) Enzymes work as a catalyst which allows the process of metabolism of food to go under the ordinary conditions inside the body. If we assume that you extracted the enzymes which facilitate the respiration process

in the yeast, and put them in a sugar solution, do you think this will result in:

a) All the sugar solution will change into carbon dioxide and ~alcohol.

b) Nothing will happened. This process will not take place except in the body of a living organism.

c) Some of the sugar solution will decompose into carbon dioxide and alcohol and some will stay as it is.

Mark the correct answer and justify in the space provided below.

Categories for the answers.

1-SM,CH, those who stated that some of the sugar solution would decompose and some would not because of the difficulty of circulating the same ATP and enzyme in the absence of life.

2-SM,CH,NS, those who stated that some of the solution would decompose without providing any reason for that.

3- ALL,CH, those who stated that all the sugar would decompose (beginning of 20th century theory). They recognized the importance of enzyme without recognizing the unique feature of life in circulating the same compound many time.

4-BD,ON, those who stated that respiration reaction could happen only inside the living organisms. One stated that the condition outside the body is not suitable for that (BD,ON,CN). This theory is the one hold at the middle of 19th century.

Selection: QUESTION equals 9 and TEST NO 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	1	9	ALL CH	2
CONTROL	EMAN	1	9	ALL CH	2
CONTROL	ROWLA	1	9	ALL CH	2
CONTROL	SAMAYRA	1	9	ALL CH	2
CONTROL	TAGHREYD	1	9	ALL CH	2
CONTROL	WEJDAN	1	9	ALL CH	2
CONTROL	FADWA	1	9	ALL,CH	2
CONTROL	KAREYMA	1	9	SM,CH,NS	3
CONTROL	AMAL	1	9	BD ON	0
CONTROL	HANAN	1	9	BD ON	2
EXPER	ASMA	1	9	ALL CH	2
EXPER	SALAM	1	9	ALL CH	2
EXPER	SAWSAN	1	9	ALL CH	2
EXPER	ABEAR	1	9	BD ON	0
EXPER	BASEMA	1	9	BD ON	0
EXPER	FATMA	1	9	BD ON	0

EXPER	GHAYDA	1	9	BD ON	0
EXPER	KHOOWD	1	9	BD ON	0
EXPER	OHOWD	1	9	BD ON	0
EXPER	SUMAYYA	1	9	BD ON,CN	0

Selection: TEST NO equals 2 and QUESTION equals 9

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	SAMEYRA	2	9	BD ON	0
CONTROL	AMAL	2	9	BD ON	0
CONTROL	EMAN	2	9	BD ON	0
CONTROL	HANAN	2	9	BD ON	0
CONTROL	ROWLA	2	9	BD ON	0
CONTROL	AMENA	2	9	BD,ON	0
CONTROL	FADWA	2	9	ALL,CH	2
CONTROL	KAREYMA	2	9	ALL,CH	2
CONTROL	TAGHREYD	2	9	ALL,CH	2
CONTROL	WEJDAN	2	9	ALL,CH	2
EXPER	BASEMA	2	9	ALL,CH	2
EXPER	FATMA	2	9	ALL,CH	2
EXPER	SALAM	2	9	ALL,CH	2
EXPER	SAWSAN	2	9	ALL,CH	2
EXPER	SUMAYYA	2	9	ALL,CH	2
EXPER	ABEAR	2	9	SM,CH,NS	3
EXPER	GHAYDA	2	9	SM,CH,NS	3
EXPER	OHOWD	2	9	SM,CH,NS	3
EXPER	ASMA	2	9	SM,CH	5
EXPER	KHOLOWD	2	9	SM,CH?	5

10. causes of cancer are controversial issues these days. Give your opinion by checking a, b, or c below (check only one) and your justification for it.

a) some people relate it to environmental factors

b) others for genetic factors

c) some people say both factors are important.

Categories for the answers.

1-EN GN those who stated that genetic and environment factors together cause the cancer. They stated the scientific reason, which is coming from their understanding for the working of DNA in controlling the building of enzyme.

2-EN GN NS, those who stated that both factors (environmental and genetic) collectively led to the cancer without mentioning the reasons.

3- EN OR GN, those who thought that environment or genetic could lead to the cancer.

4- GN VI EN, those who stated that environment and genetic are important factors but they thought that virus transmitted through the DNA.

5- EN, those who stated environment only as the cause of cancer (beginning of 20th century theory).

6- GN, those who stated genetic only as the cause of cancer.

Selection: QUESTION equals 10 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	1	10	EN	0
CONTROL	KAREYMA	1	10	EN	0
CONTROL	ROWLA	1	10	EN	0
CONTROL	SAMEYRA	1	10	EN	0
CONTROL	WEJDAN	1	10	EN	0
CONTROL	AMENA	1	10	EN OR GN	2
CONTROL	FADWA	1	10	EN OR GN	2
CONTROL	TAGHREYD	1	10	EN OR GN	2
CONTROL	EMAN	1	10	GN VI EN	0
CONTROL	HANAN	1	10	GN VI EN	0
EXPER	SALAM	1	10	EN	0
EXPER	BASEMA	1	10	EN GN N EX	4
EXPER	FATMA	1	10	EN GN N EX	4
EXPER	GHAYDA	1	10	EN GN N EX	4
EXPER	SAWSAN	1	10	EN GN N EX	4
EXPER	ABEAR	1	10	EN OR GN	2
EXPER	ASMA	1	10	EN OR GN	2
EXPER	KHOLOWD	1	10	EN OR GN	2
EXPER	OHOWD	1	10	EN OR GN	2
EXPER	SUMAYYA	1	10	GN	0

Selection: TEST NO equals 2 and QUESTION equals 10

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMAL	2	10	EN	0
CONTROL	FADWA	2	10	EN	0
CONTROL	ROWLA	2	10	EN	0
CONTROL	SAMEYRA	2	10	EN	0
CONTROL	HANAN	2	10	EN OR GN	2
CONTROL	KAREYMA	2	10	EN OR GN	2
CONTROL	TAGHREYD	2	10	EN OR GN	2
CONTROL	WEJDAN	2	10	EN OR GN	2
CONTROL	AMENA	2	10	EN GN NEX	4
CONTROL	EMAN	2	10	EN GN NEX	4
EXPER	FATMA	2	10	EN OR GN	2
EXPER	OHOWD	2	10	EN OR GN	2
EXPER	ABEAR	2	10	EN GN NEX	4
EXPER	BASEMA	2	10	EN GN NEX	4
EXPER	GHAYDA	2	10	EN GN NEX	4
EXPER	KHOLOWD	2	10	EN GN NEX	4
EXPER	SALAM	2	10	EN GN NEX	4

EXPER	SAWSAN	2	10	EN GN NEX	4
EXPER	SUMAYYA	2	10	EN GN NEX	4
EXPER	ASMA	2	10	EN GN	5

This is a comprehensive question for the whole issue. I want to be sure that students have a unified theory to analyse this issue.

11. Suppose there is an industry which is all automatized. This industry is specialized in synthesis clothes from petroleum ore material, it also needs another kind of oil for power supply, but at the same time robots are used to collect these ore material together for synthesis the cloth. Match these names in this industry that, with these names in a human body. Explain.

a) engineer	a) carbohydrate
b) factory manager	b) protein
c) robot	c) DNA
d) oil for power supply	d) brain
e) oil for industry	e) enzyme

Categories for the answers.

1-ALL R, those who mach all of them right

2- PR,stand for protein. CR, stand for carbohydrate. BR, stand for brain. EN, stand for enzyme. DNA stand for DNA, and whenever these codes were mentioned, it means that the student made the correct matching for this category.

Selection: QUESTION equals 11 and TEST NO equals 1

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	AMENA	1	11	ALL R	5
CONTROL	SAMEYRA	1	11	ALL R?	5
CONTROL	WEJDAN	1	11	BR	1
CONTROL	TAGHREYD	1	11	CR,BR	2
CONTROL	EMAAN	1	11	CR,BR,EN	3
CONTROL	AMAL	1	11	CR,PR	2
CONTROL	FADWA	1	11	CR,PR	2
CONTROL	HANAN	1	11	CR,PR,BR	3
CONTROL	ROWLA	1	11	CR,PR,BR	3
CONTROL	KAREYMA	1	11	NON	0
EXPER	ABEAR	1	11	All R	5
EXPER	ASMA	1	11	ALL R	5
EXPER	SALAM	1	11	ALL R	5
EXPER	FATMA	1	11	CR,PR,EN	3
EXPER	GHAYDA	1	11	CR,PR,EN	3

EXPER	KHOLOWD	1	11	CR,PR,EN	3
EXPER	SUMAYY	1	11	CR,PR,EN	3
EXPER	OHOWD	1	11	PR	1
EXPER	BASEMA	1	11	PR,BR,EN,DNA	4
EXPER	SAWSAN	1	11	CR,PR	2

Selection: TEST NO equals 2 and QUESTION equals 11

CLASS	NAME	TEST NO	QUESTION	CATEGORY	GRADE
CONTROL	WEJDAN	2	11	BR,EN	2
CONTROL	AMAL	2	11	CR,PR	2
CONTROL	FADWA	2	11	CR,PR	2
CONTROL	ROWLA	2	11	CR,PR	2
CONTROL	AMENA	2	11	ALL R	5
CONTROL	HANAN	2	11	ALL R	5
CONTROL	EMAN	2	11	ALL,R	5
CONTROL	SAMEYRA	2	11	ALL,R	5
CONTROL	TAGHREYD	2	11	ALL,R	5
CONTROL	KAREYMA	2	11	ALL.R	5
EXPER	ASMA	2	11	BR	1
EXPER	GHAYDA	2	11	BR	1
EXPER	BASEMA	2	11	BR,PR	2
EXPER	OHOWD	2	11	CR,PR,BR	3
EXPER	SAWSAN	2	11	CR,PR,EN	3
EXPER	ABEAR	2	11	ALL R	5
EXPER	FATMA	2	11	ALL,R	5
EXPER	KHOLOWD	2	11	ALL,R	5
EXPER	SALAM	2	11	ALL,R	5
EXPER	SUMAYYA	2	11	ALL,R	5